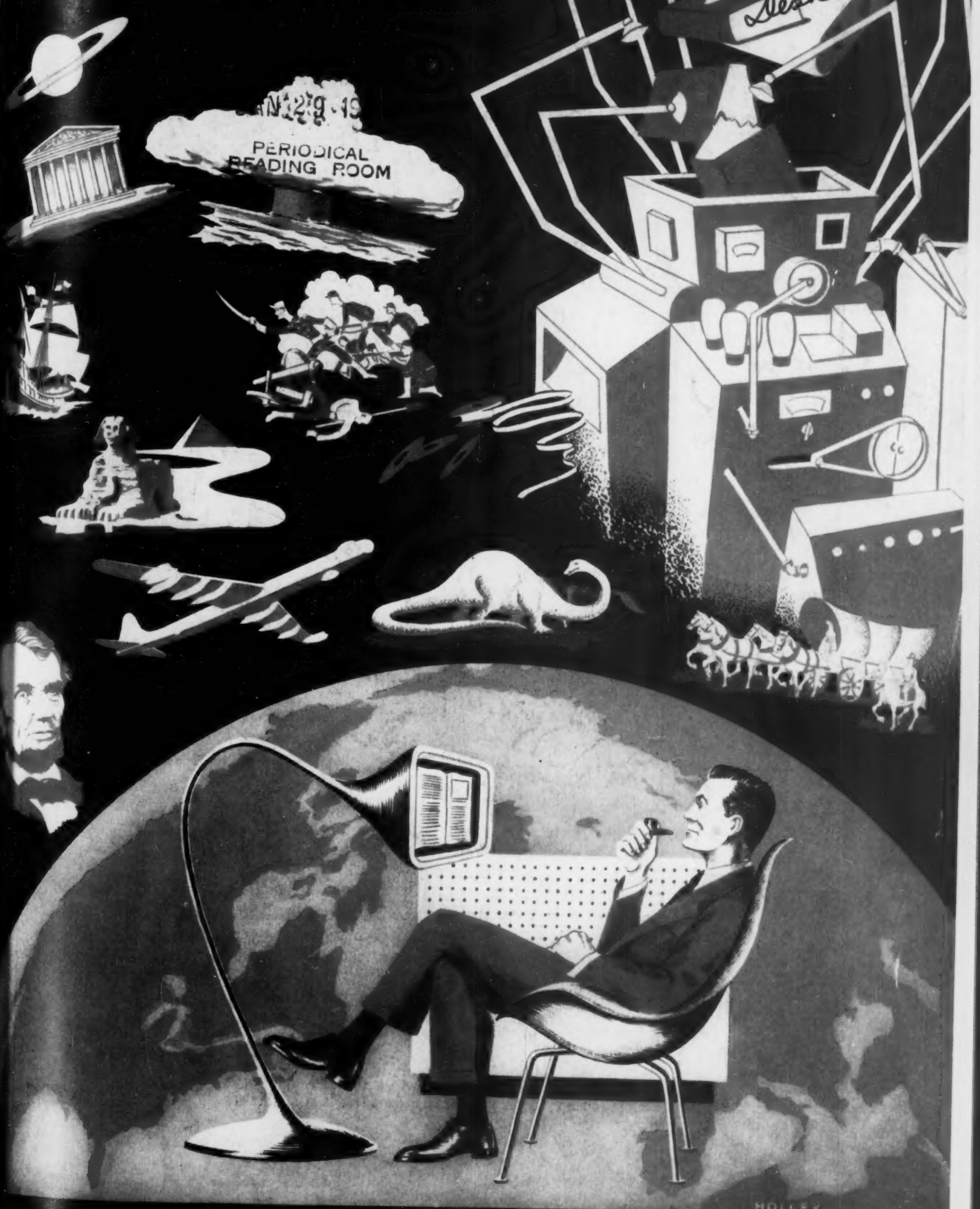
The SCIENTIFIC MONTHLY



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Contents

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Science and Technology

(From the Month's News Releases)

No Whirring Wheels this Winter

Inexpensive, heavy, durable new auto floor mats keep drivers' heels from scuffing holes in auto carpets, catch dirt and water from shoes, and make handy kneeling mats for changing tires. Made of tough Vinylite plastic, they will not harden or crack and are easy to clean with a damp cloth. High abrasion resistance of the plastic and the waffle pattern make them useful for giving traction to wheels slipping in mud, sand, or snow. They come in brown or black.

Research in the USDA

Dehydrating sweet sorghum, a new processing of an old crop, promises a better way of feeding forage crops. With the old method of curing sorghum much of the sugar was lost, and, in order to increase the palatability and energy, valuable molasses had to be added. Research has shown that sorghum retains its natural sugar when the entire crop is dehydrated. The dehydrated product may have 30 per cent or more of sugar and is as sweet as cookies. Made into meal pellets, it is easy to handle, store, and transport. The low moisture content makes the product highly resistant to insect damage.

A fast-spreading, poisonous weed, halogeton, now imperils livestock on the rangelands of six Western states, reports the USDA. A close relative of Russian thistle and a native of the Caspian Sea region, it was first noted in this country about 15 years ago in Elko County, Nev. It contains oxalic acid, which combines with calcium of the blood serum. From a half pound to a pound and a half of the weed, dry weight, will kill a sheep. Smaller amounts cause loss of weight and abortion. An annual, halogeton grows most abundantly on bare soils. It has a high water content and an unusually large root system for its size. Chemical sprays kill it but must be applied in quantity each year at high cost. Halogeton competes poorly with other plants, however, and experiments are now in progress to control it by replacement with grass.

Next—Frozen Concentrated Milk

It is now possible to produce frozen concentrated milk that will remain acceptable as a source of beverage milk for several months after it goes into frozen storage, according to recent investigations of the Bureau of Dairy Industry, USDA. In the experiments, the product was prepared by heating the milk at relatively high temperature (155° F. for 30 minutes, or 170° for 1 minute), homogenizing it at 2,500 pounds' pressure, concentrating it to one third its volume, cooling, sealing in containers, and freezing. On the basis of the research, it has been concluded that the concentrated milk should be frozen rapidly—i.e., in a few hours—and stored at not less than -10° F., the rate of freezing being less important than the storage conditions.

Mechanical Secretary

A remote-control dictation system announced by Thomas A. Edison, Inc., is designed for low-volume dictators. TeleVoice consists of from one to twenty modified telephones directly connected to a central recording instrument located near the secretary, who thus receives the work by direct wire. It has been tried out extensively in hospitals to expedite the handling of medical records.

Shoe Sole Shock Resistance

Leather soles for shoes give two to four times as much shock resistance—protection against pressure from stones and other sharp objects encountered in walking—as the same weight and thickness in the best composition soles available, researchers at the University of Cincinnati reported recently. Tests were made under varying conditions of temperature by two youthful scientists in the Tanners' Council of America Leather Research Laboratory at the university, Seymour S. Kremen and Robert A. Vickers III.

New Publications

South African Journal of Clinical Science (incorporating *Clinical Proceedings*). A publication of the University of Cape Town, Mowbray, C. P. Annual subscription, 25 s.

Courrier, a new monthly published by the International Children's Centre, 2bis, Ave. du Parc de Passy, Paris (XVIe). Each number will consist of three parts: special articles on social pediatrics; bibliographical abstracts; and brief items of information concerning work for children in various parts of the world. Annual subscription, 2,000 fr.

The British Journal for the Philosophy of Science, a publication of the Philosophy of Science Group of the British Society for the History of Science. A quarterly. Annual subscription, 30/–.

Revue de Psychologie Appliquée. Editions du Centre de Psychologie Appliquée, 15 rue Henri Heine, Paris (XVIf). Quarterly, at 1,000 fr.

Impact (mimeographed). Deals with the influence of science on society. $1.00 per year for four issues from Unesco, 19 Ave. Kleber, XVIo, Paris.

The Welch Physics Digest will contain abridged articles from numerous scientific publications. Published quarterly, and free on request to all scientists, from W. M. Welch Manufacturing Company, 1515 Sedgwick St., Chicago 10, Ill.

Artificial Weather

Following the issuance of two patents relating to the use of silver iodide for various purposes, including the precipitation of moisture in natural atmospheric clouds, General Electric Company has announced that, for the present and until further notice, it does not intend to enforce any of its patents relating to weather modification by the artificial production of snow and rain. The weather research activities of the company have been placed under Project Cirrus, a joint weather research program of the U. S. Army Signal Corps and ONR. Under this program, scientists are consultants, perform laboratory work, and analyze data for significant results. All field operations are performed by the two services.

How Many Miles per Gallon?

With the Mile-O-Meter, manufactured by Gale Hall Engineering, Inc., you can know the amount of mileage

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The Visual Apparatus as an Optical Instrument

FRANK ALLEN

Dr. Allen, professor emeritus of physics at the University of Manitoba, winner of the Tory gold medal of the Royal Society of Canada (1944), and former member of the National Research Council of Canada, is also an honorary member of the Optical Society. He has written a great deal on the general subject of color vision and physiological optics and presents in this article a stimulating synthesis of his ideas.

THE mammalian eye, with its simple dioptric system and sensitive retinal screen on which real images of external objects are formed with remarkable precision, has generally been compared with a camera. Elementary as the dioptric system is, the uncorrected eye as a whole is singularly designed to rectify the numerous defects in the image arising from the composite nature of white light, its diffraction in passing through the small pupillary aperture, and the characteristic optical aberrations of lenses.

The eye differs from a camera by its automatic power of accommodation, or focusing, for objects from about 10 inches practically to infinity, its association with color sensations, and chiefly by the fact that the real image on the retina is excessively small, whereas in a camera the image is very large.

In a telescope, the object glass, which corresponds to the lenticular system of the eye, forms a small real image of an object, which is then magnified by the eyepiece and viewed by the observer as an enlarged virtual image. Or, by suitable means, the image may be projected in extended form on a screen.

The size of the retinal image may be computed from the formula $I = \frac{O \times 15}{D}$, where I is the length of the image, O the length of the object, D the distance of the object from the eye, and 15 mm the anterior focal length of the eye. (All measurements are in millimeters.) The image of a man's face, about 22 cm × 15 cm, at distance of 2 m is about 1.6 mm × 1.1 mm. This diminutive image does not enter consciousness directly from the retina. If it did, it would scarcely be possible to detect in it all the minute particulars of form, shade, color, and expression that are to be seen in the face. Magnification of the image in some manner is obviously imperative for adequate visual analysis and perception of the entire form and its fine detail. The required magnification does occur in the visual area of the brain in a manner unparalleled in any artificial optical instrument.

While the image of an external object is formed

on the retina according to the laws of optical imagery, its reproduction in sensational form, as finally elaborated in the complex neural pathways, is presented to consciousness in the area striata of the cortex where vision actually takes place. It has been rather loosely assumed that the receptor elements of the retina are connected individually by neural fibers to corresponding percipient cells in the visual cortex, or that the one area is anatomically organized in a fashion similar to the other. Though the point-to-point projection of the retina upon the striate cortex is probably functionally correct, the area striata can no longer be regarded as a simple anatomical reproduction of the retina. Many problems of vision, such as those associated with form and visual acuity, no doubt require for their further elucidation a more complete knowledge of the striate area and its relation to the retina.

The area striata, or visual cortex, consists of a number of folds in the calcarine areas of the two cerebral hemispheres. Its size varies individually, and is also not the same in the two hemispheres. Filimonoff[1] found it to be between 2,208 mm^2 and 2,877 mm^2, or an average of 2,613 mm^2, for some cases. Duke-Elder,[2] however, states that if spread out flat it would be oval in shape, with an area of about 3,000 mm^2. The nature and degree of macular representation in the cerebral cortex have been subjects of speculation for many years, but it was found by Brouwer, Van Heuven, and Biemond in 1928 that the area striata is about evenly divided between the macular and peripheral areas of the retina. This fact implies that the fibers from the minute macular area are as numerous as those from the large peripheral region of the retina.

The area striata is concentrically surrounded by a parastriate area and an adjoining region called the peristriate area. These are termed visuopsychic areas which are concerned with visual associations. They have, therefore, no immediate function in the strictly visual processes, but they emphasize the importance of the striate area as the real organ of vision.

The visual nerves may be broadly divided into two classes, those of macular origin, and the peripheral fibers. The macular nerves are usually regarded as comprising at least one third of the total, though this proportion may be an understatement. Zwanenburg[3] estimated that 65 per cent of the ganglion cells are concentrated in the central region of the retina, within a radius of 2.7 mm about the fovea, and the remaining 35 per cent in the rest of the retina, with a similar proportion of fibers in the optic nerve. The true macular nerves may therefore comprise, as Elliot Smith affirms,[4] nearly half the whole number. Whatever the exact numbers may be, there is a huge preponderance of macular fibers, which gives the central area its paramount importance in vision. Although the area of the retina does not seem to have been measured, calculation from the dimensions of the eye indicates the functional area to be about 905 mm^2, about one half the full area of the eyeball, or about 1,200 mm^2 if it covers two thirds of the total. Of this amount the macula, with a diameter of 2 mm, comprises an area of about 3 mm^2, and the periphery, the remainder of about 900 mm^2, assuming the smaller area of the retina. One half the area striata, 1,500 mm^2, therefore subserves the macular area of 3 mm^2, the other half the periphery. The ratio of the macula to the corresponding striate area is therefore 3:1500, or 1:500, and that of the periphery to its corresponding cortical area, 900:1500, or 1:1.7. These are average ratios for the whole areas, assuming that the fibers from the macular and peripheral areas are spread evenly over the corresponding striate areas, which is far from being the case.

These ratios are further based on the assumption that each macula is bilaterally represented and projected onto each calcarine area, which has not been completely proved.[5] Marshall and Talbot[6] state, however, that from the study of electrical localization "the field map on the cortex taken through the ipsilateral eye coincides with that through the contralateral. That is, a given field point seen through either eye projects electrically to the same cortical point; just as a small cortical lesion produces homologous scotomas in the two eyes."

Since no observable change in the size of an image occurs in passing from the periphery to the fovea, it is probable that, as the concentration of receptors, especially of cones, which function predominantly in form vision, gradually increases toward the fovea, there is a converse expansion of the striate terminals toward the foveal cortex, for which the increased numbers of fibers in the optic radiations, 5 million, as compared with those of the optic nerve (500,000), provide the neural apparatus. Whereas the retinal macular image has an average expansion, or enlargement, of about 500 times its size in the striate macular area, the retinal foveal image may be enlarged many times that figure in the foveal cortex.

In this connection it may be remarked that derangements of form do occasionally occur, but they are entirely pathological. Under these abnormal conditions the retinal elements become either

crowded together or spread apart, so that in the one case more cones are excited than in the normal state and fewer in the other. In the former condition, the enlargement of the image is known as retinal macropsia, and in the latter the contraction is called retinal micropsia. These occurrences serve to indicate, however, that an unevenly graduated, or irregular, concentration of visual elements either in the retina or the area striata would be detected by a distortion of form.

Marshall and Talbot[7] state that

> since a pattern 1 minute of arc wide at the retina subtends in geometrical terms about 5 μ or 2 cones, at the cortex this expands 100 times linearly or 10,000 times in area. . . . It should be emphasized that this expansion is in each visual unit-path and is quite distinct from the functional and anatomical spread due to reciprocal overlap between adjacent paths. We interpret this as a refinement of the cortical mosaic over the retinal, by a large factor. [The same authors state that] the most unfavorable values that can be used would make the initial cortical mosaic over 30 times as fine-grained as the retina; and that this ratio would be increased over 20 times by including the cells in the thickness of the initial sublayer.
>
> But quantitatively [they continue] the unit-paths near central vision should now be conceived, not as lines, but as expanding cylinders [rather, truncated cones] whose ends bear an area ratio of 1:10,000, and a cellular ratio of perhaps 1:100. . . . We must conclude that there is one primary cortical locus for each foveal cone. But multiplication of path makes that locus a group of cortical cells, which would all have nearly equivalent connections to the retinal cone.

The large cortical areas corresponding to the retinal cones are not distinct from one another, but overlap to some extent. The direct overlap of ascending neurons is, however, at a minimum in the fovea centralis and increases toward the periphery. These conditions are of much importance in the explanation of visual acuity.

The area of the fovea is about 0.05 mm². If this area is expanded in the foveal cortex 500 times, the cortical area of a foveal image would be about 25 mm² and, if expanded 10,000 times, its cortical area would be about 500 mm² (1 sq. in. = 645 mm²). To perceive in an image of 0.05 mm² the fine delineations of form and the gradations of shade and color, with their contrasting modifications, would border on the miraculous. But in an image expanded or magnified to 500 mm², the discrimination of details would easily be possible. These figures for the cortical enlargement of the foveal image are extremes. Because of the overlapping of striate areas, the expanded image will be reduced in size from the larger value by an unknown amount—probably by more than one half. But, as experience shows, the size of the striate image is sufficiently large to provide for the great acuity of vision, or for the perception of the finest detail. The peripheral retinal images also experience some striate expansion, except possibly those in the extreme region, but it is comparatively small, and the greater cortical overlapping will render the image indistinct, as observation shows to be the case.

Should any defects exist in the retinal image as a result of the chromatic aberrations arising from the composite nature of white light and the monochromatic aberrations of the refracting media, they will likewise experience striate magnification. In normal vision defects are unnoticed, which proves that the retinal image is remarkably perfect. The slight indistinctness of the retinal image in near sight, far sight, and astigmatism becomes so greatly magnified in the striate cortex that clear vision is impossible. Although glasses restore the perfection of the retinal image, fitting them for the eyes is strictly a striate rather than a retinal process, for the degree of correction is judged not immediately by the retinal but by the striate image.

The retina as a whole can function for many hours without perceptible fatigue, but it is probable that the rods and cones individually lose their responsiveness quickly for a short time. Doubtless, like muscle fibers, they function in relays, for, if all responded at once, any excitation would always be visually of blinding intensity. The vast number of receptors in the retina, and the still greater number of cortical cells, provide ample groups of relays, so that vision proceeds steadily without perceptible displacement or impairment of the image.

Effective vision involves both the retina with its minute images and the striate area with their enlargements as an eyepiece or a viewing screen. The varied requirements of the eyes, especially their rapid mobility and accurate coordination, call for a small globe easily and swiftly turning from one position to another in order to scan in detail the object under visual examination. If the area of the retina were to be increased to the striate size, the enlarged eye would be sluggish in movement, subject to muscular fatigue, as well as greatly disproportional to the area of the face and the depth of the orbit. The increased retinal area would be mostly wasted, since only a very small proportion can receive attention at a time. An image of much enlarged size would be impossible to produce without radically redesigning the whole dioptric system of the eye in a form probably impracticable with living tissues. By the existing arrangement the great advantages of small mobile eyes are all retained, and at the same time the necessary magnification of images is effected by an ingenious and simple

neuromechanical device. An optical magnification would evenly cover the whole image; but the neuromechanical magnification is finely graduated for the direction of attention to a few details at a time. A more admirable system of vision can scarcely be imagined.

In contrast with the apparatus of vision comprising a small retina and a large cortical viewing area, the cutaneous senses are at the opposite extreme, for the adult skin has an area of 1.6 m^2, or 1,600,000 mm^2. The cortical tactile area is probably smaller than the visual, and may conveniently be taken, for purposes of illustration, as 1,600 mm^2. The areal ratio is then 1,600,000:1,600, or 1,000:1. That is, an average area of possibly 1,000 mm^2 of the skin is represented on about 1 mm^2 of the cortex. Consequently, tactile as well as warmth and cold discrimination for simultaneous contact of two points over most of the surface of the body is relatively coarse. When two touch spots on the skin are stimulated, they are perceived as separate at distances apart ranging from 0.1 mm on the finger tips to 1.5 mm on the abdomen. But when touch spots are disregarded, the discrimination ranges from about 11 mm for the palm to 67 mm for the middle of the back, though on the tips of the tongue and fingers it varies from 1.1 to 2.3 mm, respectively, which would be cortically represented by about 0.001 mm. These comparative measurements suggest that there is an enlarged cortical tactile "macular" area, analogous to that in the visual cortex, on which the tongue and fingers are widely represented. When cutaneous distances are compared with retinal, the acuity of touch is more than 3,000 times less delicate than that of vision. The striate area magnifies the macular image, whereas the tactile cortex minimizes what may be termed the tactual image.

The relationship of the area striata to the retina suggests that the visual apparatus as a whole much resembles a telescope, in which the eye is the objective, the striate area is the magnifying eyepiece, and consciousness is the observer. Since optical magnification of the retinal image is out of the question, the unique device of neuromechanical magnification is effectually substituted for it. An optical eyepiece would have to be constantly maintained in rigid alignment with the objective, which would seriously interfere with the mobility of vision. But the neural connection between the two parts of the visual apparatus renders alignment superfluous. There is sufficient slack—7 mm—in the orbital part of the optic nerve to give the eye the utmost possible freedom of motion without interfering with neural conduction and the function of the striate area. Such flexibility of performance in artificial optical instruments is impossible to obtain, and is an important particular in demonstrating the superiority of the apparatus of vision over all optical instruments.

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THE FAR-SEEING EYE

THE great eye turns, and suddenly we see
Far stellar systems as they used to be
Before man was—now his to view and know
Worlds as they were a billion years ago.

We hear the psalmist in his wonder say,
"A thousand years to Him is but a day!"
Now, once a distant nebula has beckoned,
A thousand million years is but a second.

TEMPLE RICE HOLLCROFT

A Résumé of Researches at the Arizona Meteorite Crater

H. H. NININGER

The fall of a huge fireball that he witnessed in 1923 turned Dr. Nininger from a summertime enthusiast to a full-time geologist. In 1946, with his wife (and co-worker), he opened the American Meteorite Museum on U. S. Highway 66 opposite the great Arizona Crater. Unlike his predecessors, he believed that the crater could best be understood by studying the distribution of meteoritic particles around it rather than by probing its interior. As a result of his extensive investigations in Arizona and elsewhere, he has developed several new hypotheses, which are incorporated in An Introduction to Meteoritics, *soon to appear.*

IT HAS been almost sixty years since the attention of scientists was first called to the strange topographical feature now known variously as Meteor Crater, the Arizona Meteorite Crater, and Barringer Crater. So far as can be learned, A. E. Foote[1] was the first to be attracted to the problem of explaining its origin. After a brief visit to inspect the site of a remarkable concentration of meteorites, he mentioned the fact that the many nickel-iron masses were found near the base of a circular elevation whose center was "occupied by a cavity nearly three-fourths mile in diameter," the bottom of which was far below the surrounding plain. He gave a brief description of the feature, closing with the statement that he was unable to find any volcanic products and was "therefore unable to explain the cause of this remarkable geological phenomenon."

Shortly thereafter, G. K. Gilbert[2] inspected the phenomenon and concluded that it had been the result of a steam explosion, volcanic in nature. This conclusion may seem strange in the light of present knowledge, especially since Gilbert was such an outstanding geologist. But it should be remembered that up to that time meteorite craters had not been known to exist.

It is to D. M. Barringer and his associates that must go the credit for first recognizing and more or less establishing the meteoritic origin of the crater, and to them we are also indebted for a great body of facts regarding the structure and general characteristics of the phenomenon. At great expense of time and money, these men worked intermittently during the first three decades of this century at various types of exploration—chiefly with a view to commercial exploitation, it is true, but in the process they brought to light much useful information concerning the crater. In a monograph[3] read before the autumn meeting of the National Academy of Sciences in 1909, Barringer summarized the results of several years of exploration, and in later papers[4] he recorded additional findings which, he thought, gave further verification of the opinions expressed at that time.

In the present paper frequent references will be made to these reports. Our admiration for the pioneer work of Barringer has been set forth in *A Comet Strikes the Earth*,[5] and, even though our opinions, having been modified by the discovery of several new facts, are not now in full agreement with those of Barringer, our respect for the man's determination and persistence remains unchanged.

The topographical aspects of the crater as determined by Barringer are as follows: Diameter of pit at crest of rim, 4,150 feet; elevation of rim above adjoining plain, 120–168 feet; average elevation of crest above lowest point in present floor, 570 feet; vertical distance from highest point of crest to center of present floor, 600 feet; width of rim entire, inclusive of outlying mounds of ejecta, 1–2 miles, with the bulky portion varying from 1,000 to 2,500 feet in width. As determined by drillings, the extreme depth to undisturbed sediments in the pit is 1,000–1,200 feet below the surrounding plain. Approximately the lower half of the pit is filled with fragmental rock and water, the water level being about 200 feet below the center of the present floor.

The name "Canyon Diablo" was applied to the meteorites from this area before their relation to the crater was recognized. Their description by A. E. Foote in 1891 was based on a study of the metallic

masses first recovered by a prospector and shipped from Canyon Diablo Post Office; hence the name. Such masses were later reported by Barringer as having been found as far as 6 miles distant, on three sides of the pit. These ranged in weight up to several hundred pounds, and a very few even exceeded 1,000 pounds.

Small irons of 5 pounds or less were found in great abundance on the outer slope of the northeastern sector of the rim and less abundantly in several other areas, some as far distant as 2 or 3 miles from the pit. As will be pointed out later, it is probably significant that these outlying scatterings of small irons, with the exception of those on the north-northwest, have been found in association with larger masses, whereas those on the rim slope were not accompanied by masses of more than 10–15 pounds, except for one instance where a mass of approximately 100 pounds was found about midway of the outer rim slope.

Chips and flakes of iron-nickel oxide were found irregularly scattered on all sides of the pit to distances of 3 and 4 miles and in a few areas much farther out. These were usually more abundant in the areas where metallic masses, either large or small, were recovered. Their presence was frequently used by meteorite hunters as a guide to areas likely to yield metallic meteorites.

Another form of iron-nickel oxide that was widely scattered both on the rim and on the plain appeared as nodular masses of various sizes and shapes. These usually displayed deep cracks or fissures, the result of internal expansion as the oxidation of metals proceeded inward from the surface. They were named "shale balls"—rather ineptly, since they are really neither shale nor by any means always ball-shaped. Actually, they exhibit an almost unlimited variety of forms, though they tend to be nodular, with ends, corners, and edges rounded. A considerable percentage do appear more or less rounded, and an even greater proportion somewhat pear- or drop-shaped, often with one side flattish. But some are quite elongated, flattish, and variously contorted in general form. Some of the shale balls have metallic cores, and Barringer at first seemed to think that the shale-ball meteorites represented a distinct variety of individual mass in space. But in view of his study of some that contained metallic cores he seems to have later concluded that all the metallic masses were residual cores left by the flaking away of the "shale-ball iron" that originally enveloped them. With this view we are not in agreement, as will be discussed later.

Particles of nickel-iron oxide were reported recovered from 17 of 31 drill holes in the crater and including one from the crest of the southern rim. According to the drilling logs that were kept, in

Aerial view of Arizona Meteorite Crater from about 15 degrees south of due east. Canyon Diablo is shown in background. Monument Rock is indicated by the arrow. This marks the mideastern point on the rim.

two of the holes drilled in the southwestern quarter of the pit and in the one from the crest of the south rim, impenetrable masses were encountered which, after persistent hammering, were by-passed. After several repetitions of this behavior, the drill bits were lost, probably becoming entangled among such fragments.

Some of the particles of nickel-iron oxide recovered had metallic centers that would not crush in a mortar. Barringer interpreted these as "sparks" stripped from the outside of the mass as it came into contact with the rock strata through which it penetrated. He was not sure whether these "metallic centers" were true nickel-iron or schreibersite.

The Barringer group reported that water was encountered about 200 feet below the floor of the crater and believed that this represented an accumulation of rain water subsequent to the time the pit was produced. When they later tried to sink a shaft outside the pit at a point about 1,000 feet below the crest of the southern rim, they encountered the water at approximately the same level as inside. They believed this was due to shattering of strata beyond the limits of the pit, however, and still thought it possible to lower the water level in the pit by means of pumping, so as to permit mining operations in the bottom. A trial pumping program reportedly lowered the water level somewhat, but the calculated expense of completing the task led to the temporary abandonment of the pumping program (1929). We now know that the water level in the pit is consistent with the general water table of the surrounding country, as revealed by the drilling of several water wells a few miles from the crater.

Barringer also reported large deposits of finely pulverized quartz (produced from the Coconino formation) in the crater pit and in various parts of the rim, and he estimated that it probably amounted to as much as 10–20 per cent of the ejected material. He pointed out that this had been subjected to intense dry heat. On the other hand, in certain parts of the pit, he found deposits of fused quartz pumice that must have been, he indicated, formed in the presence of steam and at higher temperature than is known to be present in volcanoes. He further reported the absence of volcanic deposits other than ash, which had evidently blown in from volcanic craters 15–40 miles to the south and west.

Although several of his findings would have fully justified a conclusion that the meteorite had more or less completely exploded and that only a small remnant remained in the crater, Barringer clung to the idea that the principal mass of the meteorite, or cluster of meteorites, still lay buried in the pit and that it constituted an available source of valuable metals. One of the arguments against the explosion theory which Barringer regarded as incontestable was the fact that no great amount of iron stain was noticeable in the vicinity of the crater. He argued that, if the meteorite had exploded into a large volume of metallic vapor, we should now witness positive evidence of that fact in the form of widespread iron stain in the country rock. We have since learned that this reasoning was fallacious. When the Haviland crater was excavated, we found no evidence of soil staining in the area around the crater where the small nickeliferous pellets, products of vaporization, were found. Only a layer of soil a few inches thick was stained, delineating the bottom of the crater bowl, and only a narrow zone of staining surrounded each of the thousands of specimens removed, usually less than one-fourth inch in thickness.

Recent Discoveries

We believe that recently there has been brought to light sufficient evidence to prove that Barringer's conclusions were in error at several points. We believe it is now evident that there remains no considerable mass of meteoritic material in the crater, but that, rather, the colliding mass was for the most part actually vaporized upon impact. The principle has been demonstrated in experimental gunnery and has been theoretically supported by astronomers, physicists, and mathematicians who have investigated the problem mathematically. Now, new discoveries, we believe, have verified the explosion principle in fact.

With the help of the American Philosophical Society and of certain private individuals, we began seriously to explore the Barringer Crater area in 1939, believing that a thorough study of the distribution of meteoritic material around it would eventually lead to a satisfactory interpretation of the event. We began with a search of selected areas on various sides of the pit within a radial distance of 1–3 miles, using a magnetic rake. This device, attached to an automobile and carried on a small trailer, gathered small masses of an ounce or less in the upper three-quarters inch of soil.

The combing of a total of some 23 acres in many different small areas on various sides of the pit gave results that led to the belief that meteoritic material exhibited a *radial distribution,* with the crater as a center. Subsequently, an inspection of the many holes left by cowboys and others who had recovered large masses 25–1,000 pounds in weight lent further support to the theory of radial distribution.

In 1947, working on a permit from the Standard Iron Company, the American Meteorite Museum systematically searched large areas of the crater rim's outer slope for small masses (10–5,000 g), using an Army surplus mine detector and several other types of metal-finders, effective to depths of about 2 feet on masses of one pound. Here we found further evidence of radial distribution, but by comparing our results with the record made on the Holsinger map published by Barringer in 1909 we were also able to demonstrate a *general distribution of meteorites as to size*—i.e., small sizes near the crest of the rim and larger ones on the plain beyond the rim. An exception to this distribution lies in the fact that on the plains small meteorites were usually associated with the large ones; but on the rim we found no large masses associated with the abundant small ones.

Another peculiarity of distribution has been the almost complete lack of large masses in the northern-northwestern sector of the adjoining plain. This area has, however, yielded many small metallic fragments, mostly less than an ounce in weight. During our magnetic survey of 1939, this sector proved to be the most productive of any large area investigated, but the meteorites collected averaged less than 2 g in weight. The Holsinger map shows an almost complete absence of large masses in a fan-shaped area lying between radii drawn from the center of the crater 30° north of due east and 10° north of due west, but I can find no reference to indicate that any significance was attached to it. It should be noted that according to present evidence the path of the colliding meteorite just about bisected this area, a fact that is believed to be significant.

In 1946, again working with the help of the American Philosophical Society, we began a magnetometer survey to ascertain the distribution of large masses of 40 kg upward which might be buried on the plains around the crater. This program was interrupted by outside interference, but not before we had set up and taken readings on 1,032 stations, covering 23 acres along the base of the crater rim on the north and south. These stations were spaced at 30-foot intervals. Whether meteorites of size were located, we were never permitted to learn, but six very pronounced anomalies were mapped. One lesser anomaly yielded a 12-pound mass of oxide with a 3-pound metallic core, only about 12 inches below the surface.

An important fact to record from this partial survey is that the operator, A. J. Whelan, was not impressed with the possibility of a magnetic mass in the crater, but he did believe that his readings indicated something to the southeast. He later called attention to the report of International Geophysics (which was made in 1930 and detailed radial traverses leading outward from the crater) which showed abnormally high values for stations in the two traverses on the southeast. Jakosky[6] regarded this as due to local disturbances and did not use these data. Whelan suggested that there was a chance of there being a large mass lying southeast of the crater, "but if there is it will be farther out than anyone has looked to date."

We are inclined to interpret the readings in this area as due to buried meteorites near the surface, since more large masses have been found at the surface here than in any other area. We have also suspected the existence of one or more subsidiary craters such as the University of Texas found concealed by surface deposits near the principal Odessa, Texas, crater. We believe further that similar near-surface objects led Helmut Landberg to the seemingly impossible conclusion that large masses had forced themselves under the strata to distances as great as a mile south of the present pit and at depths of 1,000 feet or more.

It seems reasonable that, if large masses of metal (or oxide, which in the earth seems to develop a stronger magnetic field than does metal) existed under the south rim, then surely our east-west traverses along the base of the rim should have given strong indication of such, because those stations along the north rim were an average of about 7,000 feet north of the mid-point on the south rim where Barringer thought he had a huge mass of metal, whereas those on the south were but 2,000 feet south of the same point.

The velocity of meteorites in space at the earth's distance from the sun has been fairly well established as 20–30 miles per second. At such velocity any meteorite would explode upon striking the earth. Consequently, only those that are small enough to be effectually decelerated by the atmosphere can be expected to survive their encounter with the lithosphere. Wylie[7] has shown that iron meteorites of 220 tons or more should explode on hitting the earth. The fact that no mass larger than about 50 tons and only three larger than 30 tons have ever been found suggests that this figure is too high. Also, the excavation of the 80-foot subsidiary crater at Odessa, which plainly evidenced an explosion, and the several excavations in the Henbury craters, all indicate that many meteorites of smaller size than 30 tons actually explode on contact with the rocks of the earth. No considerable-sized mass has yet been found within any crater. A broken mass of 441 pounds was found in

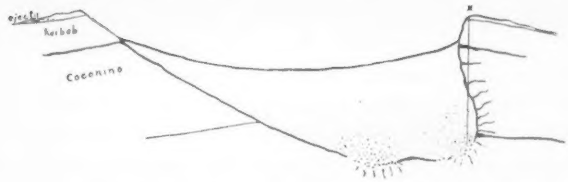
a 30-foot crater at Henbury, and three contiguous masses aggregating about 200 pounds were found in the Haviland Crater. The bowl-like bottom of this 36′ × 55′ crater was strewn with thousands of smaller fragments.

Ballistic experiments have shown that projectiles traveling at velocities above about 4,250 feet per second explode into vapor on striking the target. In the light of present knowledge we may assume that any iron meteorite of larger size than 20–30 tons has small chance of surviving its collision with the lithosphere. There are, however, mitigating circumstances, such as angle of descent, texture and slope of soil encountered, shape and texture of the meteorite, whether it overtakes or collides head-on with the earth, etc. The 36½-ton Cape York iron landed on a 15-degree slope in a latitude where deep snow is the rule. Otherwise it might not have survived. The Hoba iron of perhaps 50 tons presents a problem; but it is of great age and may have arrived when conditions in that area were very different.

In view of these facts it at first seems surprising that any fragments of the great Arizona mass remain. However, a careful consideration of its structure seems to have brought to light a very sound reason for the survival of so many fragments.

We pointed out, in a paper read before the American Astronomical Society in Tucson (December 1949), that the unequal distribution of cohenite and schreibersite and abundant scattered nodules of troilite and graphite are probably responsible. These minerals are all brittle, the first two extremely so. Also, both schreibersite and troilite have low melting points. Concentrations of one or all these minerals are common in the fragments that have been collected and may very well have been more abundant in areas obliterated in the fragmentation process. Such a condition may have occasioned a superficial shattering of the mass upon its first contact with the lithosphere. Fragments so detached were thrown free and distributed over the surrounding plain, thus escaping the great heat which seconds later reduced most of the remaining mass to vapor.

During 1948 and subsequently, by studying the internal structures of hundreds of small Canyon Diablo irons found on the northeast rim of the crater during the 1947 survey, we were able to demonstrate that a *zonal distribution* existed with regard to heat effects. More than 97 per cent of the regular Canyon Diablo irons from this location appear to have been altered by heat, whereas fragments of comparable size taken from outlying points seldom show such alteration. Barringer and other



Theoretical section of the present crater. The two concentrations of fragments explain the area of high conductivity located by the electrical survey of International Geophysics in the southwestern quarter of the crater pit and that encountered by the drill as reported by Barringer. *X* shows location of the 1,376-foot drill hole. Looking eastward.

early investigators had noted that large specimens found on the plain showed beautiful Widmanstätten patterns, whereas the small ones they had sectioned revealed a pattern altered by heat. It was long believed that size was the determining factor in these results. Unfortunately no records were kept as to where these irons had been found, but it is generally assumed that the small ones came from the crater rim, since that is the area from which so many small specimens had been recovered. Our 1948 studies, however, were conducted on meteorites the places of find for which were accurately recorded. It was thus that we were able to demonstrate the relation between heat alteration and *location,* leading to the conclusion that the outlying fragments were thrown free before final vaporization, and that those found on the rim betray by their altered condition the fact that they were not set free until the explosion occurred.

The concentration of these small meteorites on the northeastern sector of the rim and their almost total absence on the western sector can probably best be explained by the fact that the prevailing winds in this area are from the southwest. At high elevations wind velocity often reaches 70 miles per hour. From a depth of 1,000–1,200 feet, surviving fragments thrown aloft several miles could very easily have drifted with the wind in their descent, so that those that did not fall into the pit spread only slightly beyond the rim to leeward. The lesser deposit of similar small masses that Holsinger indicates on the southern rim may have been a product of the initial shattering described earlier. Unfortunately we have no access to any of the fragments from that portion of the rim. Almost certainly some specimens could yet be collected, and the study of such is here suggested.

Barringer's conclusion that all the metallic specimens represent residual cores left from disintegrated shale balls, and that the holes and deep

depressions in these irons all were products of the wasting away of shale-ball iron, seems untenable. We have exhumed many irons in beds of large boulders and in various other situations where movements of the irons could not have been possible by erosion. Yet careful inspection revealed no evidence of exfoliation of any considerable amount of oxide. On the other hand, many other irons showed abundant evidence of such oxidation.

We concluded, therefore, that the shale-ball iron and the normal Canyon Diablo irons were not originally two different kinds of meteorites in space but were merely different portions of a common parent mass which in some parts was rich in one accessory mineral and in others another, and that still others were composed of pure nickel-iron. Those fragments which carried a destructive content of chlorine became the shale balls, and those that lacked it survived. There were, of course, those fragments that contained this disintegrating agent in irregular distribution. Such specimens lost their afflicted portions by rapid weathering, and other portions remained more or less immune. They were by this means reduced to all sorts of fantastic shapes, not a few being completely perforated. However, the majority of deep, narrow perforations and pits were undoubtedly due to the dissolution of troilite where the nodules of this mineral were exposed at the surface of the fragment. This has been proved in many instances by the finding of residual troilite at the bottoms of such narrow cavities.

We have found considerable evidence that the shale balls were not the product entirely of their chemical peculiarities, but that their rapid deterioration may have resulted from them, together with their exposure to greater heat than were those regarded as typical Canyon Diablo irons. Those few iron cores from the masses of oxide we have examined all appear to have had the Widmanstätten pattern altered by heat. Laboratory experiments have demonstrated that an iron which contains a trace of chlorine, and which has been resisting oxidation very well, may disintegrate rapidly after being subjected to a temperature sufficient to induce redness. It may be that the large lumps of oxide (shale balls) represent those masses which contained some chlorine and which also received a little more heat than did the average. This is a point on which we feel we have as yet insufficient evidence to justify final conclusions, but our findings seem significant.

What we believe to be conclusive evidence of the vaporization of the bulk of the meteorite has recently been provided by the discovery of five different forms of particles which evidently constituted the condensation products from an iron vapor cloud. Such a cloud we believe to have been the product of the great impact-explosion. Great quantities of minute spherules and droplets of nickel-iron have been found in an area of more than a hundred square miles with the crater near its center. These have been collected magnetically from many locations and have been quantitatively estimated at several thousand per cubic foot in the topsoil 4 miles due north of the crater rim. They are much more abundant nearer the crater and along the base of the rim, but gradually thin out as one recedes from the crater. These were first identified early in 1948 as an ingredient of the fine, dark-colored debris that so abundantly clings to a magnet when dragged through or over the surface of the soil. That they had eluded all investigators during the past half century is easily explained by their being so greatly overshadowed by the much more abundant particles of basaltic cinders, many of which are also magnetic, and with which they are likely to be confused until critically examined under a lens.

A preliminary account of our discovery of these particles was reported to the American Philosophical Society in 1949. That report dealt only with the two forms of the condensation droplets that were first isolated. The more important ingredient of this metallic rain which is here discussed we only succeeded in separating out in September 1949—too late for incorporation in the 1949 report. This is in the form of a rounded particle, with a more or less lumpy surface, as though it had been produced by the accretion of several smaller droplets during the process of condensation and solidification. A critical examination of the surfaces establishes the fact that at least the larger ones (those measuring 0.3 mm or more) are not residual cores of larger bodies which have oxidized but, rather, are complete individual particles which have not suffered loss of mass since their formation. They have developed a very thin skin of oxide which seems to have been impervious to the forces of weathering, so that the body of the particle is for the most part untarnished metal.

Probably the most difficult problem presented by the discovery of these condensation products is the explanation of their survival. If the crater was formed twenty to fifty thousand years ago, then one should surely not expect such minute bodies of ferrous metal to be still resisting oxidation. Even more amazing is it that they should have escaped being ground to impalpable powder. Yet here they are! We may assume that their resistance to oxida-

tion has been due to the formation of a thin, impervious layer of oxide while the droplets were in the liquid stage and during solidification. This protective film was similar to that found on the best-protected areas of a freshly fallen metallic meteorite. We recovered two masses of the Glorieta meteorite fifty-three years after the discovery of that iron, whose date of fall is unknown. These masses still exhibited patches of the original fusion crust unstained by rust. They were quite as fresh-looking as those that had been placed in museums in 1884. This find gives evidence that a fusion crust of oxide may be an extremely effective protection for ferrous alloys.

As to their escaping destruction by trituration, it should be noted that the best locations in which to search for them is on the leeward (northeastern) side of boulders or clumps of vegetation. In such situations they might rest undisturbed for long periods and, since the topsoil is dry most of the time, their being covered would protect them from moisture.

The recent reports on the great cosmo-terrestrial encounter near Novopokrovka in southeastern Siberia in 1947 give point not only to the discovery of this metallic rain but also to other aspects of the theory of explosion of large meteorites on contact with our planet. It was with no small satisfaction that we read in Otto Struve's[8] translation of the Russian report on this great meteorite the account of the "rain of iron," the Arizona counterpart of which we had been investigating for the past two years.

Besides the spherules above described we have isolated and identified the following condensation products: (1) Metal-centered pellets which are minute globules of bright nickel-iron encased in a few layers of soil and sand grains. (2) Reticulated pellets consisting of soil and sand particles bound together by a reticulum of nickel-iron oxides. These often are flattened on one side as if the metal had landed in liquid form and incorporated the soil particles within the liquid droplet. (3) Near-perfect spheres of nickel-iron oxide which apparently condensed from those portions of the vapor cloud exposed to oxygen and which oxidized previous to or during solidification. (4) Globules of silica glass coated with oxides as if a droplet of silica had cooled and subsequently received a deposit of metallic condensation before reaching the soil. This form of silica glass resembles that described by L. J. Spencer and M. H. Hey[9] in connection with the Henbury craters in Australia. Details of the nature and varieties of the metallic particles deposited at Novopokrovka are not available. It will be interesting to note what subsequent reports reveal on this point.

In addition to the little silica-glass droplets, we found a small amount of the better-known form of silica glass, which had never previously been reported from the Arizona Crater. This is a transparent glass with a greenish-yellow tint and contains minute metallic spheres, or droplets. Black and brown varieties were found in abundance at the Henbury craters and a clear white variety at the Wabar craters, all described by Spencer and Hey. The Arizona find was in the form of small angular blocks and shreds up to one-half inch in greatest dimension. It was found on the north rim of the crater about halfway up the outer slope and was gathered by means of a magnet while searching for the metallic droplets.

The structural studies of the Canyon Diablo meteorites that we have been conducting during the past few years have revealed further important evidence concerning the nature of the meteoritic encounter that produced the Arizona Crater. The American Meteorite Laboratory began sectioning the small Canyon Diablo meteorites in the 1930s and in 1938 encountered one that exhibited good Widmanstätten figures but of a pattern that did not conform to the well-known Canyon Diablo structure. Subsequently, two other small irons were cut that conformed to this new type, which was described as Canyon Diablo No. 2.

Later, two more new types were studied and catalogued as Canyon Diablo No. 3 and as Monument Rock (the latter so named from its nearness to the huge boulder on the crest of the east rim of the crater, to which Barringer gave that name). Canyon Diablo No. 3, like No. 2, has been found in duplicate, but so far only one group of fragments (evidently from a single mass) of the Monument Rock find has been recovered. In view of the fact that all these three new types have been gathered from the crater rim, and the further fact that they were found among but about 200 specimens critically examined, we regard them as very good evidence that the crater-forming mass was accompanied by more or less of a swarm. In other words, this appears to have been a multiple fall. We estimate that 40,000 small specimens have been collected from the crater rim since its discovery. Assuming the same ratio as our studies have yielded, we should expect quite a number more of non-Canyon Diablo types to have been among these. We here suggest that those who have irons from the crater might do well to section and study them.

The normal Canyon Diablo irons show great

variation among themselves, and some of those variations, we surmise, would be difficult to distinguish from an altered Canyon Diablo No. 2 or No. 3. However, we have not as yet to our knowledge seen No. 3 in altered form. (We have several problematical specimens laid aside for further study.) The limits of the variations in the normal Canyon Diablo meteorites have been determined by an extensive inspection of many large sections in our own and other large collections, involving careful measurements of the kamacite plates, with critical notes on taenite and other less conspicuous characters. Nothing is regarded as *non*-Canyon Diablo unless it is plainly inconsistent with all the different variations observed in any of these sections. Identifications are difficult, and we had examined at least a hundred sections before we became convinced that the fall was a composite one consisting of two or more components. Even after Canyon Diablo No. 2 was described in 1938, we were not sure but that it may have represented a later fall in the same area. It showed less heat alteration than the typical Canyon Diablo irons with which it had been associated on the rim and could therefore be thought of as a chance overlapping of a subsequent fall. However, when in 1947 and 1948 we discovered two additional types it seemed entirely unreasonable to assume that so many falls of nickel-iron meteorites should be recovered from so small an area. Besides, we had by this time found several more of Canyon Diablo No. 2, and some that showed heat alteration similar to what had been suffered by typical Canyon Diablo fragments on this same portion of the crater rim that we suspect of being Canyon Diablo No. 2.

We were now wholly convinced of the multiple nature of the impact and we strongly suspected that we had been missing the identity of specimens which represented the components of this multiple system, or swarm, in instances where the latter had suffered heat alteration. We are still more convinced of this error since becoming conscious of the existence of these various components among the heat-altered specimens. We have now learned how to distinguish them even when the Widmanstätten pattern has been largely obliterated. In one instance, 2 specimens of Canyon Diablo No. 2 were recognized among 30 specimens cut. Both were free from heat alteration. In another lot of 24 irons, 5 were non-Canyon Diablo components, 2 of which had been altered by heat. Two other lots of 15 and 7 irons all proved to be of the typical Canyon Diablo. These four lots are typical of our recent investigations of crater material.

A, Etched section of typical Canyon Diablo meteorite showing Widmanstätten pattern and nodules of troilite and graphite surrounded by narrow borders of schreibersite. Several cohenite inclusions near lower edge. × ½.

B, Another typical Canyon Diablo section; here heat has largely obliterated the Widmanstätten pattern. This also contains abundant cohenite, which conforms to the original pattern. × ½.

C, Etched section of Canyon Diablo No. 3. Note much greater prominence of taenite separating the kamacite bands. × 1.3.

D, Etched section of Canyon Diablo No. 2. In this specimen the structure is deformed but still quite distinct. × ½.

Present Interpretation

Barringer's final conclusion was that the crater was formed by a closely packed swarm of small meteorites. Moulton[10] admitted such a possibility and always made allowance for this condition in his calculations; but he found some serious difficulties in explaining all the facts on this basis. Jakosky always referred to "the meteorite or swarm of meteorites." Our recent finds give positive evidence that the encounter was a multiple one, but we think they with equal positiveness argue against

the kind of swarm indicated by these men. We believe that the many widely scattered masses on the plains around the crater, which show the same range of structures, and which have come to be recognized as the Canyon Diablo meteorites, have been derived from one large mass. We refer to both those that show heat alteration and those that do not, so long as they compare favorably as to widths of kamacite plates, arrangement of taenite and plessite, and their inclusions of carbide, phosphide, troilite, and graphite.

We believe that the comparative scarceness of Canyon Diablo No. 3 and of Monument Rock indicates that these represent very minor masses that were satellites of the Canyon Diablo body. But the greater abundance of Canyon Diablo No. 2, and the fact that it occurs in both the unaltered and heat-altered conditions, indicate that it represents a second large mass that underwent considerable fragmentation before it finally disintegrated upon impact. These facts may best be explained by assuming two large masses constituting a sort of miniature earth-moon system, accompanied by a family of smaller masses.

Jakosky assumed an angle of incidence of about 70° from the horizontal, but did not submit any special reason for selecting that angle. For several reasons, we have chosen to assume a much flatter trajectory, of about 30° with the horizontal. This is chosen because: (1) It seems to better explain the shape and structure of the crater. (2) The great majority of observed meteorite encounters have been at angles less than 40° with the horizontal. We refer here, of course, to the trajectories of the fireball stage of meteorites, not the much steeper angle at which ordinary meteorites strike the soil. Certainly crater-forming meteorites would be checked but little by atmospheric friction and would therefore arrive at the lithosphere at approximately the same angle of descent as marked their encounter with the atmosphere. (3) The lower angle of approach better fits the distribution of meteoritic material around the crater. (4) The reported concentration of meteoritic material under the southern rim suggests a flat trajectory.

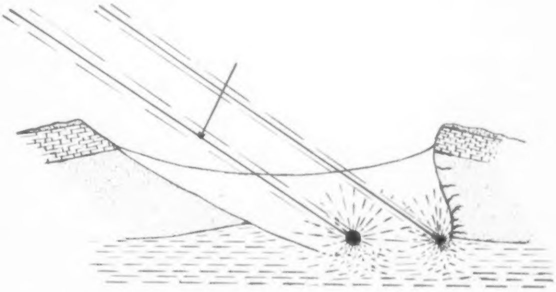
We assume that on its very first contact with the lithosphere, the principal colliding mass shattered in certain weak outer portions. The fragments thus set free were thrown with great force but were spared any great heat penetration, the heat being restricted largely to the shearing planes. These were naturally thrown forward, laterally, and upward from the exposed areas of the meteorite's surface. That portion of the surface which made the initial contact with solid sediments was vaporized instantly, as quickly as it came into contact with the sediments, and set free no sizable fragments. The discharge from this portion was in the form of gases and very small shreds, and constituted a backfire from the missile. This would seem to offer the best explanation for the lack of large fragments in the segment of the plains adjoining the crater on the north-northwest, which, as has been pointed out, was the direction from which the meteorite approached.

It is on either side of this axis that the crater walls are most steeply upturned, and the fields of large boulders lie on the outer slopes of these steeply dipping strata. It is also at the distal end of this line of flight that the magnetometer survey of Jakosky indicated a concentration of metalliferous material.

The southern rim is somewhat arched, but dips only slightly away from the pit. These features were interpreted by Barringer as indicating a large meteoritic mass wedged under the rim. Jakosky, however, has pointed out that this southern section of the rim is stratigraphically lower than the sections on either side of it, so that it is quite as important to explain the positions of these latter as it is to explain the southern section.

Several forces combined to form the crater:

1) The impact splash in itself was sufficient to produce the present surface dimensions. A high-velocity bullet fired into packed dry sand forms a crater twenty to thirty times the diameter of the projectile. As Alfred Wegener long since pointed out, the coherent strength of the target material is of no great consequence when forces of such magnitude as is represented by impacts of large meteorites are involved; sand behaves about the same as the toughest rock.



The author's conception of how the Arizona Crater was formed by primary and secondary meteoritic masses. The larger mass on the left was responsible for the normal Canyon Diablo irons and was the chief force in the excavation of the crater. The smaller one followed a few seconds later and was responsible for the Canyon Diablo No. 2 fragments. Arrow points to location where the larger mass underwent a superficial fragmentation as it first encountered the rock strata, at the same time opening the way for mass No. 2. Looking eastward.

2) Closely related—in fact, one aspect of the impact force, but producing a special kind of result—was the plowing or burrowing action, the lateral and upward displacement of rock strata which were torn free from their axial moorings. We here refer to the tilting of strata, a part of which was the result of impact and part a result of forces yet to be considered.

3) The expansion of highly compressed air that had been captured on the front of the moving projectile as it traversed the atmosphere was another of the factors. The magnitude of this force would depend upon the angle at which the passage was accomplished. Descending vertically, the pocket of air should be the equivalent of a layer of rock about 14 feet thick, according to Moulton, but coming in at an angle of 40 degrees or less it could be very much greater. It should also be borne in mind that the dimensions of this air cap would be much greater than the diameter of the meteorite, because each layer of impacted air becomes a trap for more, and so the cap grew in lateral as well as in axial dimensions. This superheated block of air operated as a powerful explosive laterally and upward as it made its escape from the trap into which it was being driven between the projectile and solidly bedded rock. It wreaked havoc in the porous sandstone of the Coconino.

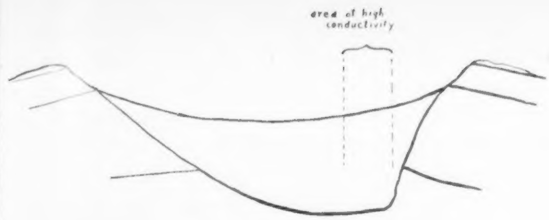
4) The fourth factor was steam. The pores of the lower Coconino sandstone were filled with water, and this was heated both by impact and by compression. The resulting violent rise in temperature transformed the water into steam under conditions of pressure which rendered it an extremely powerful explosive. Already distributed among the sand grains of the formation, the entire mass, as far as the heat and pressure effects were sufficiently felt, disintegrated in a mighty blast. This blast was a protracted one, the superheated steam becoming active as the pressure and temperature conditions reached the critical levels; i.e., as that portion of the rock near the source of heat was removed, the pressure was reduced in deeper layers, thus allowing more of the superheated fluid to participate in the distintegrating process.

5) Finally came the greatest explosion of all, when the internal temperature of the nickel-iron mass had reached the critical point where the mass was suddenly transformed into metallic vapor. This was a blast of mountain-shattering proportions. It was this that gave final form to the crater in all its principal outlines. It was this explosion also that propelled skyward the gigantic metallic-vapor cloud from which rained down the millions of condensed-vapor droplets recently discovered in the field. At the same instant the thousands of small fragments that survived the blast were released. Since they were shot aloft from the depths of the pit before the crater vent had fully formed, they had but a narrow distribution. Obviously, nothing very large escaped from this final blast, which accounts for the absence of sizable fragments on the rim.

No mass of metal, however, as heterogeneous as that represented by the Canyon Diablo meteorites, could possibly explode completely. With its several included minerals, some of which have low melting points, together with the highly crystalline character of the nickel-iron, certain portions would certainly absorb more than their due share of the heat and disrupt the mass while certain other portions were at a safe temperature for survival. But, as we know the structure of the meteorite from a study of hundreds of samples, it is certainly not to be expected that any great masses survived. In all probability those that have been collected (many thousands in number) around the pit are entirely representative in size of whatever are buried in it.

This final explosion had much to do with the ultimate shaping of the crater. It removed a roughly circular, conical block of the overlying Coconino and Kaibab, and its downward thrust also excavated some of the underlying red beds. The side walls, whose uptilting had already begun as a result of the plowing action, lifted in degrees proportional to their nearness to the explosive force. The south wall, which had been somewhat arched by the tunneling action, was uplifted by this most powerful thrust of all. The compressed Coconino, together with meteorite fragments, was wedged into the gap. At the same time the steam action was ripping out the support for this uplifted block on either side, where escape was provided by major faults and by the upedged side walls. The uplifted overhanging south wall was sheared off by the upward thrust of the blast. The anchored portion dropped back into place as nearly as the underwedging permitted. The steam action adjacent to the faults at either end undercut this block, allowing its east and west edges to slump and thus accentuating the arching effect.

The above would seem to account for such a crater as was depicted by Jakosky (a sketch of which is presented herewith), but it still fails to explain the reported encounter by the churn drill of numerous sizable fragments under the southern rim at depths of 1,191–1,376 feet, as we have interpreted the log of that hole. Poorly kept as that log seems to have been, our study of it did not allow any alternative to the assumption of numer-



Longitudinal section of Arizona Crater as conceived by Jakosky after the surveys of International Geophysics, 1930. Looking eastward.

ous fragments at the depths indicated. We were equally convinced that there was no large mass encountered.

The Jakosky survey pointed to a magnetic high some 800–1,200 feet northwest from this drill hole, namely, in the southwestern quarter of the pit. This location may be assumed to be that marking the resting place of the remnants of the mass which we have followed to its explosive demise, its path being a curved one because of the earth's rotation during the period consumed by its traversal of some 1,800 feet of rock formations. But still to be accounted for is the concentration of fragments encountered by the drill under the south rim.

As stated above, we have found positive evidence that this was a multiple fall, that there were several (perhaps many) components involved in the encounter. Recent studies show that at least one of these (Canyon Diablo No. 2) contributed to the abundant deposit of small, heat-altered fragments that are collected from the crater rim. Our incomplete quantitative studies on this point indicate that perhaps 10 per cent of the fragments collected from the rim were contributed by non-Canyon Diablo components, at least one of which underwent an explosive treatment similar to that of the principal mass.

We shall therefore postulate a satellite of the main mass, which reached the earth slightly later than its principle. It was trailing its principle and was describing an orbit averaging some 800 feet from the line of flight of the main mass, and struck before the south wall had settled into place. Upon impact it repeated the last act described for the larger mass but on a smaller scale. Its remnants were for the most part trapped under the southern rim, but an easy path of escape allowed certain of them to escape to the northward through the opening made by its leader.

Future Researches

The cosmo-terrestrial encounter that has been responsible for this great crater was probably far more complicated than the above effort at visualization depicts, but at least this would seem to be an outline of what may have taken place. No doubt a better interpretation can be arrived at by a more complete examination of the surviving fragments. Ours has been the first attempt to relate the various structural features of the meteorites to their distribution around the crater. It appears now that this method of approach, if followed to its logical conclusion and carefully correlated to geophysical, topographical, and geological features, may eventually lead to an adequate understanding of this outstanding landmark.

It is suggested that various university groups could address themselves to different aspects of the phenomenon (offhand, at least twenty problems come to mind, each worthy of several years' effort) and in time make this phenomenon yield as valuable a body of data as does a well-equipped observatory or the field program of any department of geology. For example, since we now have positive proof of the existence of non-Canyon Diablo irons among the small specimens found on the rim, a critical study of the largest possible number of these should be made to ascertain how many different species composed the swarm. In addition, our proposed magnetometer search of the surrounding plain for the larger members of the assumed swarm should be regarded as vital by astronomers who seek further information regarding comets.

Again, we have no satisfactory evidence of the diameter of that swarm. We cannot be certain that various reports of irons being found 7, 10, 17, and 30 miles from the crater were actually deposited in these locations from the swarm that belonged to the crater-forming mass, but these reports cannot be ignored in any adequate survey. On the other hand, we cannot be justified in assuming that there are not many more outliers to be recovered and studied.

Only comparatively few of the several hundred large masses that have been collected in the vicinity of the crater were ever sectioned and studied so as to determine their identity. We have seen at least one of these whose structure appeared to represent a different meteorite. Perhaps a study of 50 or more would reveal the multiple character of these widely scattered masses.

Barringer reported the finding of meteorites in some of the excavations on the crater rim, thus proving that their presence was not limited to the surface. But no quantitative estimate was attempted as to the amount of material thus concealed in the ejecta. In 1948 we recovered 68 meteorites

from a few cubic yards of the diggings that the Barringer party had excavated from certain trenches on the northeast sector of the rim. A careful search of several measured sections completely through the blanket of ejecta should be made to determine with some degree of accuracy the vertical distribution and the approximate quantity of meteoritic material.

Assuming that the deposit of meteorites on and in the outer rim slope has resulted from an explosive action in the pit, it seems inevitable that similar material should have been deposited on the inner slope against the upturned wall of the pit. Excavations into and through the talus that conceals the lower portions of this wall, accompanied by the use of electronic detectors, should throw more light on the nature of the crater-forming process.

The extent and distribution of the fused silica, lechatelierite, in the pit should be determined.

Samples could be recovered from the meteoritic masses encountered by the drill under the south rim and examined for trace elements to determine their possible identity with normal Canyon Diablo, or with Canyon Diablo No. 2. Harrison Brown, of the Institute for Nuclear Studies at the University of Chicago, found these two to be readily distinguishable by his recently developed technique.

An extensive reconnaissance should be carried out north-northwest of the crater to a distance of 20 miles or so to ascertain if strippings representing the fiery trail of the colliding comet's course through the atmosphere can be found. The terrain is very favorable for such a search, being almost entirely free from contamination by human industry.

In brief, this greatest of reasonably fresh impact craters, fresh enough for fruitful investigation, should be regarded as a top item for research on the part of both geologists and astronomers. For the latter it can supply a body of facts which may constitute a much-needed anchor in material substance for certain theories. For the former it is the major example of a process in cosmo-dynamic geology which has doubtless played an important role in the history of our planet. The fact that it represents a process that operates intermittently and at remote intervals makes it doubly important that this one prime example be thoroughly understood. Such an understanding will doubtless lead to the recognition and useful interpretation of many larger scars of impact, such as that recently described by Reginald Daly[11] in Africa. Without doubt cosmic impact is a process that must find a more prominent place in future geological theory.

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New World Crop Plants in Asia Minor*

JACK R. HARLAN

The author is a geneticist with the Division of Forage Crops and Diseases of the Department of Agriculture's Southern Great Plains Field Station, which is located at Woodward, Oklahoma. He was formerly a botanist with the Division of Plant Exploration and Introduction, and his article is based on observations made during a plant exploration expedition in Turkey in 1948.

THE behavior of New World crop plants in the Old World provides special problems of biological interest. In cases where a crop plant is known to be a New World domesticate its history in the Old World cannot exceed some 450 years. Such plants were introduced into a new environment within historical times, and in some cases the number of generations can be calculated with reasonable accuracy. Their behavior and development therefore can be used as a gauge to measure the speed of evolution under conditions of primitive husbandry, and much can be learned of the processes by which cultivated plants have developed since the dawn of agriculture. These problems, then, are not only of fundamental interest to the student of evolution, but also to the agronomist and plant breeder, who are called upon to speed up these evolutionary processes in the never-ending search for new and better plant materials.

It is evident from the geographic patterns of crop diversity that these forces do not operate uniformly the world over. Some regions are characterized by a peculiar intensity of evolutionary activity of crop plants, whereas others demonstrate a considerable stability of domestic forms. Asia Minor is one of the several regions of the world where the evolutionary forces operate with especial intensity and should, therefore, be a region of great interest to students of cultivated plants.

Most biologists are familiar with the work of N. I. Vavilov, the great Russian agronomist who accomplished the most complete global analysis of our crop plants. He found most of the varietal wealth of our major crop plants to be concentrated in eight basic world centers of diversity.[1] He pointed out that these eight centers are separated one from the other by great deserts or mountain ranges. Only in Asia Minor do two basic centers overlap. As a result, this part of the world is immensely rich in varietal resources of nearly a hundred species of cultivated plants. Whatever the forces are that permit or encourage the accumulation of varieties, they must act with an intensity and regularity known in few other places in the world.

It is for this reason that the behavior of New World plants in Asia Minor is of biological significance. What evolutionary activity may be detected in these recent historical introductions into such a region? How have the new plants responded to the old forces that have generated such diversification in so many indigenous crops? Most important of all, can we identify the forces involved?

The squashes, cushaws, and pumpkins are New World domesticates of particular interest here. This group is represented principally by the species *Cucurbita pepo*, *C. moschata*, and *C. maxima*, which can be traced with considerable accuracy to their places of origin in the Western Hemisphere.[2] *C. pepo* provides a good test for the Vavilovian method. Vavilov did not know the true origin of the domesticate, but after surveying the world gene centers he unhesitatingly placed the world center of diversity for *C. pepo* in Anatolia. It has since been demonstrated conclusively that *C. pepo* is a domesticate of the North American Indian.[3] It is probable that the primary introduction of this cultigen into Asia Minor did not take place until the seventeenth century. Since that time the crop has developed such a wonderful array of varieties, forms, and types that Vavilov had no choice but to list Asia Minor as the world center of diversity for the species.

* Contribution of Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, ARA, USDA.

The cushaws, *C. moschata,* are found less extensively in Asia Minor, but are also represented by a considerable diversity. *C. maxima* is found only occasionally and in no great diversity. It may be significant that the cushaws are Central American in origin, and that *C. maxima* is a southern South American domesticate that has reached Anatolia more recently and in fewer forms.

Corn (*Zea mays*) and the common bean (*Phaseolus vulgaris*) exhibit a development somewhat similar to that of the cucurbits. The Turkish corn belt is located along the Black Sea coast. Here mountains plunge directly into the sea, interrupting rain clouds and generating a humid, subtropical climate that closely resembles an eastern Central American coast. The staple crops are corn and beans; the cash crop is tobacco. The corrugated iron roofs, unpainted wooden shutters, and grassy cobblestone streets of the coastal villages all add to the illusion, so that the traveler finds it difficult to believe he is far removed from the coasts of Honduras or Guatemala. In this narrow belt of near-tropical climate, corn and beans seem to have found a second home, for the varietal development of both is remarkable.

The most famous of the New World crops in Turkey is the tobacco plant. The Turkish aromatic tobaccos have acquired such a reputation that American tobacco companies feel obliged to pay premium prices for Near Eastern leaf, and the simple phrase "Turkish-American blend" has sold nearly as many cigarettes as pin-up girls and give-away shows. In monetary value more than half the total export trade of Turkey is tobacco. The various tobacco-growing regions of Turkey have developed their own varieties, adapted to local conditions and differing considerably in quality and type. Despite the distinctness of the Turkish aromatics, the variation exhibited scarcely warrants the establishment of a secondary center of diversity. At least the variation in no way approaches that of corn, beans, and New World cucurbits.

We may place in the same category red pepper, (*Capsicum frutescens*), tomato (*Lycopersicon esculentum*), and sunflower (*Helianthus annuus*). They are all New World domesticates widely grown in Asia Minor. They show a considerable varietal diversity without being sufficiently variable to warrant the establishment of a world center of diversity. Such great American gifts as the peanut and potato are grown on a very small scale by the Turks, and American cotton, the only other important New World domesticate in Asia Minor, is limited by law to a form of *Acala*.

It is evident, then, that some New World domesticates were able to find situations in Asia Minor congenial to the accumulation of variant forms. Since about one hundred other domesticated plants have similarly developed centers of diversity in the same region, it would seem that there are definite forces operating in Asia Minor to produce or maintain diversity in crop plants. These forces are of extreme interest to biologists.

Unfortunately no direct experimental attack has yet been attempted to determine the forces involved. We must for the time being content ourselves with projecting experience gained from experimental work into a field where very little research has been done. This is not a highly desirable procedure, but it sometimes leads to important results.

The remarkable geographic concentration of variant forms seen in gene centers is an evolutionary phenomenon and therefore requires a genetic explanation. Evolution proceeds through a balance of more or less opposing forces. The forces of mutation, including inversions, translocations, deletions, aneuploidy, and polyploidy, tend to produce new and variant types. The forces of selection tend to eliminate all but those types best suited to the given situation. Whatever the mutation rate may be—and there is no reason to suppose it is greater in Asia Minor than elsewhere—an accumulation of variants could not take place if the selection pressure were too strong. If selection pressure is weak, or even favors variant types, we may expect in due course an accumulation of variable populations and numerous varieties.

I list below some of the factors that apparently play a role in reducing selection pressure, or even produce selection pressure in favor of variants:

a) *Climate.* The climate must be congenial to the development of the species. Actual experimental trials[4] have shown that the variants in a mixed population will be retained for many generations in some localities, whereas all but one or two may be eliminated in a very few generations at other localities.

b) *Subsistence agriculture.* Farming on a cash basis increases uniformity. Such a farmer cannot afford mixed populations and low-yielding varieties. He has special market requirements for his produce and he must continually select for uniformity, yield, and sale value. The farmer who merely supports his family and counts on very little cash income can afford mixed populations and, indeed, will frequently select odd, interesting, off-type plants and grow them simply for his own amusement. There is little doubt that this is one reason for the great wealth of cucurbit types in

Asia Minor. Farmers derive a very real pleasure from growing types and varieties that their neighbors do not have.

c) Primitive or nonmechanized husbandry. Mechanization of farming increases the uniformity of crop plants, by planting and harvesting crops in a short space of time. Under nonmechanized farming the soil is prepared over a long period of time, planting is a long, drawn-out affair, and harvest extends over a long period. Thus mixed populations are favored, and selection pressure is somewhat in favor of variant types.

d) Extensive culture. Large populations are influenced less by selection pressure than small populations. Cultivation on a large scale indicates local interest in the crop and provides more opportunity for farmers to select and develop variant forms and local varieties.

e) Historical continuity. A reasonably long historical continuity of an agrarian society helps to maintain selection pressure at a low value. Empires may come and empires may go, but an agrarian society is likely to preserve its habits, its methods of husbandry, and its crops. Total displacement of one society by another may wipe out a gene center entirely. This has in fact taken place in North America, where the old indigenous Indian varieties of several species are nearly or quite extinct.

There are quite possibly other factors involved. In attempting to explain the phenomenon of gene centers, Vavilov[1,5] stressed the ecological diversity of the mountainous regions in which they were found, the primitive husbandry, remoteness from civilization, and similar factors. He gave the impression that a gene center was a sort of museum of forms and types which had arisen over the centuries and had been preserved by the primitive husbandry of primitive people under isolated conditions. The fact that New World crops have developed an extensive diversity in a relatively short time in a new part of the world is proof that a gene center is the result of active evolutionary processes. Ecological diversity merely compounds the factor of climate. The many local climates in Asia Minor provide an opportunity for many crops to find suitable climates for diversification. Nonmechanized subsistence farming plays a role, as indicated, but isolation and remoteness from civilization are of little significance in themselves. New standard varieties from the experiment stations have simply not yet reached the remote and isolated communities and have not displaced the mixed populations now being grown. Great varietal diversity in a given crop may be found on the plains or in the mountains, close to metropolitan areas, or in remote isolated sections.[6] Isolation in itself does not seem to have much influence here.

There are also certain natural forces operating in the development of geographic variation patterns which are unassociated with man. This is clearly demonstrable, since wild plants have their gene centers, too. Hybridity between rather widely divergent types is almost invariably involved in such cases. Hybridity has been shown by Griggs[7] to be an active motive force in evolution, and there is much experimental evidence to show that crossing between remote relatives often causes genetic unbalance that results in higher mutation rates and the development of diversification. In the case of the New World domesticates in Asia Minor, however, hybridity with indigenous forms is probably no great factor.

It is indeed unfortunate that so little research has been done in a field that promises so much toward an understanding of the evolutionary development of our crop plants. The lessons we might learn through an experimental attack on the field populations in Turkey might be of inestimable value not only to a fundamental understanding of evolutionary processes but also in the practical fields of agronomy and plant breeding.

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Blueprint for Knowledge

FRED L. WALKER, JR.

Colonel Walker's current article on "Blueprint for Knowledge," or how to be your own librarian in one easy lesson, is the result of two and one-half years as chief of the Scientific Information Section, Army General Staff, in research and development. In this capacity Colonel Walker represented the Army on various interdepartmental committees, including the Research and Development Board Committee on Technical Information. With the exception of the "electrecord," all innovations discussed here exist in a developmental stage.

FUTURE generations might bestow on our present era any number of resounding and appropriate names: "Atomic Age," "Air Age," "Age of Social Security," to name but a few. It is an even bet, however, that none would be so well deserved as the simple sobriquet "Age of Ignorance."

In the past hundred years the number of books on our shelves has multiplied a thousand times, but the amount of all this vast information that each of us can digest and carry in his head has not increased by a single line. If you consider the flood of knowledge available in print in contrast to the minute portion that each of us puts to use, the extent of our ignorance is apparent. Meanwhile, science has been piling up new masses of information at an ever faster rate, whereas our ability to absorb it remains at a standstill. It is as though we were prospectors who owned a mountain of ore without any means of smelting more than a bucketful at a time.

Naturally, we hate to think of it in just this way. We prefer to say that because our knowledge is really so "vast" it has become necessary to "specialize" in order to learn enough about a narrow subject to be a success. Specialists, of course, are learned men and can hardly be considered "ignorant." Some of them may be "quacks" (those who tell us what we do not want to believe), but others (there are always a few) who tell us what we are willing to accept are "brilliant" and have "marvelous" reputations.

We say it takes more and more years of specialized schooling to become a bona fide specialist, and that specialists who have been too long out of school are too old to be really good any more because they have old ideas and are out of touch with the times. We say we haven't time to read all the literature cluttering up the market even if we could afford to buy it and maintain a private library. So we leave it to some professional critic, editor, or Book-of-the-Month Club to tell us what we ought to read in the small time we do have. We say government and politics have become too complicated to really understand, so we simply vote for some loyal Democrat (or Republican) and rely on him and the party to work out the details. We say there are two sides to every question and so, on really big issues, we glance hastily at the headlines and keep an "open mind" until forced by threat of famine or the prod of a bayonet to "make a decision."

Most of us, in fact, just say, "The devil with it. Let the boys with bifocals figure it out," and take shelter at the nearest movie, ball park, trout stream, or gambling casino. We are ignorant, all right—not because we know too little, but because we know too much and do not know how to digest and make use of it all. The fact is that we have been tracking down knowledge for the past fifty years in the same way we once tracked down and exploited our other natural resources—rapidly, recklessly, and wastefully, like plainsmen shooting down whole herds of buffalo to lie and rot after the hunters had extracted a few choice steaks and trophies. As a result there is so much printed matter entombed on so many millions of shelves, and such a large number of new volumes being printed daily, that the mere thought of keeping up with a tiny fraction of it is depressing.

Furthermore, our ignorance has a more ominous result, for it means that ordinary men must rely more and more upon a small group of "experts"—politicians, scientists, writers, news commentators—to tell them what is going on in the world, what they should believe and disbelieve, and what they should vote for. Never, since the first high priest made human sacrifice under a Stone Age moon,

have men been more entirely at the mercy of their witch doctors.

The Real Frontiers

The reason for all this is plain. Man's path from the jungle darkness toward the light of understanding has run into a barrier—a sheer, impassable cliff that hems in further advance on every side: the limited size and capacity of the human memory. Until fairly recently, an educated man could digest and carry in his mind the bulk of the world's significant written knowledge. Such a thing is far beyond the realm of possibility today and is becoming more so at an accelerated rate. It is evident that unless this barrier is passed men can have only incomplete knowledge and partial understanding, so that they must live in mutual disagreement and doubt and can be easily misled.

This is not the first time men have encountered such a block to further intellectual advance, but each time they have found a way to overcome it. The first such barrier was crossed when spoken language came into use. The invention of written language, with portable tablets of wax, clay, and papyrus to write upon, surmounted the second fundamental barrier, for until then men could neither record and accumulate knowledge from one generation to the next nor reason logically beyond one or two rudimentary steps.

The third barrier was passed with the invention of movable type and successive improvements in the printing press, for without the ensuing flood of inexpensive books only a rare few were privileged to read and write and use their intellects, and the rest, being ignorant, were incapable of understanding or accepting such slow progress as had been made by the few. This advance alone made possible the highly developed technology and industrial productivity of our present era, which demands a technically trained and highly organized society to maintain it.

In such manner was each of the barriers passed, impassable though each must have seemed at the time. With each obstacle successfully crossed, a world of new possibilities opened, and totally new ways of living and thinking arose. The really great frontiers have always been frontiers of knowledge rather than of geography.

Today's New Frontier

If, then, we could go beyond the present barrier and actually increase the powers of the human memory to an unlimited degree, we would find ourselves on a new frontier as wide and strange as any of the previous ones—as different compared to our world of printing presses and bookshelves as our world is different from the medieval world of goose quills and illuminated parchments.

Well, why not? Of course, no one expects actually to enlarge the brain as you would stretch a shoe, but it isn't necessary to tamper with the brain at all. Memory is nothing but the process of digesting information and storing it where it can be conveniently forgotten, and then brought back in a hurry when wanted. Information can be stored outside the brain as well as inside, just so it is properly digested and can be gotten hold of quickly when needed. Some kind of "mechanical memory" would do, if it could be a small, low-cost gadget that would fit comfortably into any office or private study and that would be easy to use.

This is not as much like asking for the moon spread with strawberry jam as it may sound. There has been no really fundamental change or improvement in the techniques of filing, indexing, and finding information since Ptolemy built the great Egyptian library at Alexandria in the fourth century B.C. In this rapidly changing world it would appear that some new models are long overdue.

If scientists can design a hydrogen bomb or an ENIAC, which completes a million years of mathematical calculations in a matter of seconds, they ought to be able to build a mechanical memory that could "memorize" several million printed volumes and flash up information at will on some sort of television screen. In fact, the idea of a mechanical memory is not new. Notably, it has been proposed in the past by Vannevar Bush.

The Automatic Electronic Library

Just as a crude idea, one approach to this problem might be to design an "automatic electronic library," to which the customer could refer by remote control. We start out with a conventional library of the ancient type and we simply mechanize it. Instead of printing the information in books and stacking it on shelves, we make a recording of each document—a phonograph record or a wire recording—and provide an automatic electric record player so that when the right buttons are punched the right records will "play." Then add a wire communication network like a telephone or telegraph system, so that the records can "play" by remote control over a loud-speaker or automatic typewriter anywhere. All you need now is an automatic dial central in place of the librarian and a dialing mechanism in each customer's home. In its crudest form that would be an automatic electronic library: a sort of super "Music by Muzak" arrangement, except that it would dispense printed

information and pictures instead of music, and upon request instead of by prepared program leaving no choice to the consumer.

By the time you had recorded 8 or 10 million books and documents in such a system, you would end up with a remote-controlled "nickelodeon" approximately the size of the Pentagon Building, no doubt with marble pillars instead of chromium strips on the outside. Obviously some shrinkage would be called for. By a program of miniaturization the over-all size would have to be reduced to at least something approximating the size of a normal city library. Further, miniaturization far beyond that point would be highly desirable, if not essential, since a single system would then serve many thousands of customers scattered over a wide area and the per capita cost would therefore be reasonable.

All this is, of course, an imperfect picture of what the end product might be, but before we go into any more of the mechanical details, let us take a better look at the system and see how it would work in everyday life.

We adjourn to the country home of J. Pierpont Doakes, a successful but fairly common man of the early 1980s. Doakes (to whom we shall refer more familiarly as "J. D." from now on) has just had his breakfast eggs and coffee, has finished reading "Little Abner," and has decided to visit the library to perform some important research. Being rather intellectual, he is, in fact, making a study of the "Sex Life of the Indian Elephant under Conditions of Extreme Cold," although for our purpose he could just as well be interested in the biographies of the world's ten most famous baseball players, or early forms of the boogiewoogie in darkest Africa, or any other subject of general interest.

Across the hall is the library—for no one ever leaves home to visit a library in 1980. The library is remarkable in several respects—that is, from our antiquated viewpoint. One is immediately impressed by the fact that it contains no books, although there is a small cabinet with two rows of loose-leaf binders. These binders contain no titles but are simply labeled 1 to 100,000, 100,001 to 200,000, 200,001 to 300,000, and so on. Beside the cabinet is a small stand containing several file drawers for $3'' \times 5''$ cards. These are similar to those in use in past years, but the front of each drawer is honeycombed with small holes and has a knob instead of the conventional brass pull.

There is a comfortable armchair by the picture window, and beside it is an object that looks like a console model of a combination radio and adding machine. At least, it has a loud-speaker and all the normal tuning knobs you would expect to find on a radio, plus an extra panel containing thirty-odd columns of push buttons with ten buttons to a column, and several special dials and buttons off to one side. Right beside this thing is another gadget which looks at first like a giant floor model of a gooseneck desk lamp. On closer inspection it is actually seen to be a television screen mounted on a floor stand with a flexible shaft so that it may be bent over to face in any direction at any level to suit the convenience of the observer.

Near the cabinet containing the loose-leaf binders is a desk—just a plain ordinary desk with the usual claptrap of papers, pens, pencils, writing tablets, and pipes. To offset its appearance of humdrum normality, however, there is a lazy-arm extension fastened to the near-by wall, and on the end of it is a flat metal plate about the size of a loose-leaf binder, with several spring clamps around the edges. A square box, about $6'' \times 5'' \times 4''$ in size, with a small window in one end, rests on top of this plate. The room is otherwise comfortably furnished and decorated like any private library.

Relaxing into the chair by the window, J. D. thumbs through what appears to be a pocket-size telephone directory. He refers to several different pages in the book, each time punching one or two buttons on the control panel (the "adding machine" part) of the radio beside his chair. This done, he lays the directory aside, punches one of the colored control buttons at the side of the control panel, leans back, and buries himself in a magazine.

Several moments later a green signal light flashes on the control panel, accompanied by a tone signal. J. D. turns his attention back to the instrument, which is now connected to the New York City branch of "Knowledge Incorporated," an automatic electronic library such as we have been discussing.

Adjusting himself in the chair for peak comfort, J. D. pulls the flexible gooseneck of the television stand over until the screen is in position directly in front of his eyes at the right angle and reading distance. Then he pushes a starting button on the control panel.

Instantly an image of a printed page appears on the screen. Sure enough, it is the title sheet of a scientific report on the sex life of Indian elephants, and after a few seconds to permit hasty scanning, it disappears, only to be instantly replaced by page 1 of the same document, then pages 2 and 3, and so on through the entire report, and through other books and documents in succession. By turning one of the control dials, J. D. controls the speed with

which the page images go by, sometimes stopping a page completely until he reads it through and at other times whirling through a hundred pages in the twinkling of an eye. Sometimes he reads only the title sheet, which contains a brief summary of the book or document, and then goes immediately to the title sheet of the next document. Even when he chooses to scan an entire report, the machine does not take every page but sometimes skips from place to place, picking out only those chapters and pages that contain information bearing on the subject. By reversing the controls, the machine can be made to scan backwards in the same way, so that J. D. can return to a page of special interest and reread it from time to time. Charts, photographs, and even moving pictures, relieve the monotony of the printed word.

In this way the sex life of the elephant is laid completely and shamelessly bare before J. D.'s rapt gaze, with the effortless ease and imagery of memory itself. At the same time, J. D., who is a more or less average citizen, cannot afford to tie up the long-distance network of Knowledge Incorporated for too long a time. As he scans hastily through titles, summaries, and occasional whole pages or chapters, his hand is busy at the control panel pushing one or another of the control buttons when he desires to have a microfilm copy made of a particular page or document for further reference, or when he wants a title listed so that he can order a complete printed copy from the library later on.

At length, when he has exhausted all the information of interest to him, J. D. disconnects the long-distance line. Now he can study in more detail the selected information that has been printed on microfilm inside his receiving instrument. This microfilm copy has been printed by a special device, which consists of a miniature television screen in front of which microfilm is exposed, thus producing negative microphotographs. The microfilm strip then passes automatically through a "dry developer" and is ready for use in a few seconds. By reversing the process the film can be passed back in front of the television screen, which this time transmits an enlarged image from the film onto J. D.'s reading screen. (This process is practically identical with RCA Ultrafax, a communication method developed by Radio Corporation of America immediately following World War II.)

Meanwhile, another receiving gadget—an automatic typewriter of sorts—has produced a printed list, on a sort of ticker tape, of the titles and identifying numbers of those books and documents which J. D. selected and of which he wants printed copies for further study. This list is merely for his information, for a duplicate list has also been produced simultaneously by another automatic typewriter in the New York branch library, and a clerk is already busy there collecting the desired documents, which he will place in the midmorning mail for delivery to J. D. that evening or next day.

It can be seen that in a matter of minutes, at the cost of a few dollars, J. D. has visited a great library hundreds of miles away, screened its contents, and obtained copies of extracts of everything he wants. The same undertaking today would require a personal visit, covering at least two or three days, to the library in New York, and might well run into many months if attempted by correspondence. Even then, many of the reference books could not be withdrawn from the library and would not be available at all without a personal visit. To top it off, J. D. has done all this in comfort, without even changing from his bathrobe and slippers.

What J. D. receives from New York in the evening mail is not what we might expect. It is simply a manila envelope containing thirty or forty standard letter-size pages covered with printing. Each sheet, upon closer inspection, is seen to contain twenty-five pages printed in miniature on each side of the paper—fifty pages in all on the front and back of the sheet. At the top of each sheet, printed in full-sized type is the title, author, filing code number, and other index information on the book, magazine, or other document to which the page belongs. Each sheet contains marginal holes for filing in loose-leaf binders. Each complete document has clipped onto it a 3″ × 5″ index card with printed index information at the top, and holes for mechanical filing and selection in the bottom. Included in the envelope is a mimeographed notice which says: "Retain this material for your file. Do not return to library." Evidently the stuff is so cheap that they don't want to be bothered with keeping records and refiling it.

When J. D. receives this material he removes all the index cards and, gathering them into one hand, he opens one of the 3″ × 5″ file drawers, at random, and drops them in behind the other cards. Then he sits down at the desk and pulls the lazy-arm attachment over in front of him. This is, of course, a reading device for the miniature print. Picking out one document in which he is particularly interested, he places it on top of the metal holding plate and adjusts the spring clamps to hold it there. Then he sets the "reading box" on top of the page with the window toward him and switches on a light inside the box. The box (which weighs only a few ounces) is held in place by magnetic attraction to the metal holding plate, but may be moved easily

from place to place by hand. When J. D. looks into the viewing window, which is about ten inches from his eyes at normal reading distance, he sees a magnified image of one of the miniature pages printed on the sheet. It is of normal reading size, and the entire page is clear and easy to read without a trace of the distortion that comes from a magnifying glass.

J. D. sits back in a comfortable position, adjusting the lazy arm to match. Sliding the reading box from one miniature page to another, he reads the material just as he would an ordinary book—and with equal facility and convenience. To turn the page, he merely lifts up the reading box, flips the page over in the usual way, and sets the box down on the new page.

When he finishes studying the material, he files it in the loose-leaf binders on the bookshelf. Each document is filed according to the library number printed on its upper edge in the correspondingly numbered binder. It is easy, then, to pick out any one by number, once the number has been determined from the index cards in the file drawers.

Let's see how this mechanical card file works. It seems simple enough. The cards are code-punched, apparently using the same code as that for the television control panel. All J. D. does after looking up the code number is to insert a long metal needle into the corresponding code hole in the end of the file drawer. The needles extend through the full length of the drawer, passing through corresponding code holes in all the index cards. Then J. D. opens the drawer, turns the knob 90 degrees, and pulls out the code pins. All the desired cards are now standing up an inch higher than the others, with the printed title, index number, etc., exposed to view. When he has finished looking up the material, J. D. pushes the exposed cards down among the others and closes the drawer. Nothing to it. (This mechanical card file is similar to one first patented in 1950.)

Citizens who are not so prosperous as J. D. dispense with the more costly luxury of the television screen and microfilm records. They rent from Knowledge Incorporated only a small box containing the coding panel with its thirty columns of push buttons and the automatic typewriter. However, they still have all the printed knowledge of the world at their disposal on 24-hour notice or less, at a cost roughly the same as that of dial telephone service.

So much for J. Pierpont Doakes and his automatic library. It is not hard to see how useful a setup like that would be for government, business, scientists, and private citizens alike. On the spur of the moment, at the touch of a finger, any man could know as much about any particular problem as the man who represents him in Congress, or the doctor who wants to remove his spleen, or the news commentator who harangues him on the radio. Where would that leave the carpetbagger or the quack, or the merchant of hysteria?

To the student, in particular, the mechanical memory would open a brave new world—one in which he could learn to use his mind for creative thought and analysis instead of cramming it with masses of memorized information of limited extent and doubtful value.

We have painted a pretty picture. Unfortunately several major elements are missing. Although many of the tools needed to make the dream a reality exist today, still others are yet to be produced. To be exact, there are four new basic tools required before the automatic library can become a practical fact, instead of an unreal fantasy. They are:

1. The "Electrecord"—an electronic recording "cell" in which visual or oral information can be stored electrically and which can be made to "play" back or reproduce the information merely by passing an electric current through it without any moving mechanical parts.

2. The "Autolibrarian"—an electronic mechanism like a dial telephone system, which, when a particular code signal is dialed, will instantly and automatically select from several million "electrecords" all those that correspond to the code and cause them to be "played" in succession over a radio loud-speaker, television screen, automatic typewriter, or some machine yet to be invented.

3. A "Pocket Index to World Knowledge"—a single, small, pocket-sized book in which scientist and layman alike can readily find the code number to be dialed in order to obtain any kind of desired information from an automatic library.

4. "Books without Cost"—printed information in a form so cheap that it would cost less to give it away than to keep a record of it and provide central storage space in a library.

Almost anyone can tell you that these four things are impossible. It seems obvious—just as it once seemed obvious that the world was flat, or that the horseless carriage was an impractical and temporary fad, or that men would never be able to fly faster than the speed of sound.

In spite of that, let us examine the possibilities.

The Electrecord

It was natural that the first "record player" to be discovered should be a mechanical one. A needle was accidentally scratched across a piece of

tin foil under the right circumstances and made a noise—the phonograph resulted. Later came other methods of recording sound and light signals and reproducing them—the motion picture, the wire recorder, the magnetic tape recorder, and so on. All of these have one thing in common. The "record" is made by moving the recording "medium," wax disk, film strip, or wire, past a recording device which scratches it, or changes its color, or magnetizes it in varying degrees. The record is "played" by reversing the process and feeding the same scratched disk, or colored film, or magnetized wire back through the recording device, which now acts as a transmitter and reconverts the scratches, or colors, or magnetic variations back into the original sounds or pictures. Complicated bulky machinery with many moving parts is required.

To build an automatic library of millions of such record players would be within the realm of possibility, but the cost would be astronomical, and the billions of moving parts would be constantly wearing out and breaking down. Eliminate all the moving parts, however, and both the bulk and cost of the equipment are reduced to a microscopic fraction of the original. Now there would be nothing to wear out, and dependable operation could be assured. Let us see what this involves.

Conceive, then, of a small electric cell about the size and shape of a radio vacuum tube. When connected to a battery, electric current flows through the cell. The current causes a physical or chemical change to take place by degrees within the cell in such a way that resistance to the passage of the current fluctuates, becoming greater and smaller very rapidly. As the resistance fluctuates, it causes the volume of current to increase and decrease with the same frequency, thus creating an electric signal. This signal current is fed through an amplifying system exactly like that in an electric phonograph. The amplified signal is then used to operate a loud-speaker, where the current variations are converted into sound in the usual way, producing music or conversation.

The result would be a record player operated purely by electronic means without any mechanical "pickup," turntable, or other moving parts. We might call the recording cell that made this possible an "electrecord." The electrecord could be used to record and play back light or code signals as easily as sound signals. It could operate a television screen or an electric typewriter just as well as a loud-speaker. It could transmit a recorded program at any desired speed, depending on the amount of electric power used to operate it.

A similar process takes place in an industrial electroplating bath which is used to plate baser metals with copper, silver, or gold. In this process two electrodes are immersed in a special solution that will conduct electricity. When an electric current is passed through the bath, metal atoms are transferred, in effect, from one electrode and are deposited on the other electrode, which thus becomes coated with metal. When the direction of the current is reversed the metal is transferred back to the first electrode.

By constructing a special "electroplating" bath with electrodes properly shaped and spaced, it is conceivable that the transfer of metal from one to the other could be made to take place in an orderly sequence, starting at one point on the electrode and spreading gradually to other parts. If the density of metal atoms present on the various parts of the surface of the electrode varied, the number of atoms being transferred from instant to instant would likewise fluctuate, and the current volume passing through the cell would fluctuate accordingly. In this way signals might be recorded and played back by a miniature electroplating cell.

There are other possible approaches to the problem, but it should suffice to say here that there is excellent possibility than an electrecord could be produced if sufficient research were devoted to the subject. Such an electrecord would provide a cornerstone for the electronic library and the automatic memory.

The Autolibrarian

Visualize, now, the giant nickelodeon with which we started shrunken in size by the substitution of a capsule-sized electrecord for each of the conventional phonograph or wire recordings and by the complete elimination of motors, needles, record changers and turners, and other strictly mechanical scanning devices. In place of the millions of books and documents that an ordinary library contains, our automatic library contains millions of capsules, like brain cells in a human memory, and any capsule record can be "played" merely by directing through it a current of electricity.

The trouble, however, is that the librarian still has to find the correct capsules before she can direct an electric current through them—just as previously she had to find the shelf and number of books before she could take them down and hand them to the customer. Unless something better is provided to do the job, she must still do this by thumbing through one or more drawers of index cards, copying down the numbers of the desired documents, and then making the necessary con-

nections at a central switchboard to cause the elect-records to be played. Obviously, the librarian has got to be accelerated considerably if she is going to take care of thousands of calls daily like that of our friend J. Pierpont Doakes. If we could "plug" her into an electric socket in some way and make her work at the speed of electricity—thousands of miles a second—we would have the answer.

Even if this were possible, the union probably wouldn't allow it, so something better is needed. Several methods of doing this job are under development in government and private research agencies today, although not specifically with the idea of using them to operate an automatic library. One device employs a steel tape on which would be recorded all the information from a library index card file. The recording is made by magnetizing "dots" in the metal of the tape. Depending upon the degree it is magnetized, each dot may represent any one of various numbers or letters. Each index entry includes a code number which indicates the classification of the document. This steel tape recording is passed at great speed through a scanning device, where the magnetized dots actuate a group of photoelectric cells. When these cells detect a desired code number on the tape, they in turn actuate a second group of cells which transmit all the information under that code number to a second steel tape, where it is instantly recorded in the same manner. This second steel tape containing the selected index information is fed slowly into a mechanical typewriter, which makes a typewritten copy.

Of course, the second steel tape, instead of operating a typewriter, could just as well operate an automatic switchboard, which would then make the proper connections and direct electric current through each of the selected electrecords in succession. Each electrecord, when its turn came, could then transmit its information to the television screen or to the automatic typewriter of J. Pierpont Doakes, who could control the speed of the automatic switchboard, and thus the speed of transmission, by remote control.

An autolibrarian of this type is merely a matter of engineering development, for the necessary tools and devices for different parts of the system exist today. The same thing could be done using rolls of microfilm instead of the steel tapes, with the index information recorded photographically in spots of light instead of dots of magnetism. Machines of this sort are expensive. An autolibrarian of the magnetic tape variety would cost fifty to a hundred thousand dollars. Many would be needed in an automatic library for simultaneous use by various customers. However, Knowledge Incorporated, serving hundreds of thousands or millions of customers in 1980, could well afford to have a battery of them, along with a large automatic switchboard.

In the meantime, even more efficient devices might be produced.

The Pocket Index to Knowledge

Amazing though the combination of the electrecord and the autolibrarian might be, it would be of little use, as things stand, to anyone but a trained librarian. Someone still has to push the right buttons to make even an automatic library work. Who has not had the experience of going into a large library to seek information, only to be completely discouraged at sight of the voluminous catalogues and card indexes through which he must rummage before he can even find out where to look for the information he wants? In the end it is the librarian who must interview his catalogues and produce the information. The customer feels like a hushed and awe-inspired supplicant at a mystic shrine of knowledge, and of course he is.

If the customer of the automatic library is to be his own librarian, we must first unveil the mystery and condense the catalogues to pocket size. This should not be nearly so difficult as it appears, if we understand just why present index catalogues are so bulky and hard to use. Essentially it is because they are based upon the impossible necessity of arranging books on shelves so that a customer will be able to find everything he wants to know on a single shelf. In other words, the index is supposed to guide the librarian to a particular shelf of books, just as it once guided the librarians of ancient Egypt along the temple aisles to a particular bin full of papyri. To adapt such an ancient tool to an automatic library would be like using blind horses in treadmills to generate electric power for a city the size of New York.

Everyone knows what an ordinary subject index looks like. Here is the general idea:

FIELD OF INTEREST

I Main Division	
A. Division	
1. Subdivision	(Shelf)
2. "	"
3. "	"
B. Division	
1. Subdivision	(Shelf)
2. "	"
3. "	"
II Main Division	
A. Division	
1. Subdivision	(Shelf)
2. "	"
3. "	"

B. **Division**

1. Subdivision	(Shelf)
2. "	"
3. "	"

This sort of index becomes complex and unwieldy in large libraries containing hundreds of thousands or millions of books because:

1. Customer interests seldom correspond to the subdivisions of the index. Every specialist or professional group wants the material arranged in a different way. Physicists want cameras and combustion engines grouped according to the type of optical and mechanical systems, whereas chemists want them arranged according to film processes and fuels, and manufacturers are interested in various methods of making them in a plant. Some want all the green apples together, others all the sour apples, and others are interested only in the apple sauce. Therefore, since only one group of customers can be satisfied by the shelf arrangement, the others must have a thorough knowledge of the index in order to find the scattered shreds they are hunting under many different subjects.

2. The subjects selected for the various divisions and subdivisions of the index overlap frequently and unavoidably. In order to tell where information will be found an intricate system of cross referencing has to be added.

3. A particular book or report usually contains information on a variety of subjects, yet it can only be filed on the shelf under one of them, thus requiring the use of an extensive card index with several index cards for every document filed under the several subjects with which it deals.

It should be apparent that all these complications result from an attempt to group books on shelves and at the same time to group them according to the interests of the customer—a thing that is possible only to an extremely limited degree—and then to guide the seeker of knowledge with certainty to a particular shelf, where he will find either all the knowledge he is hunting, or a reference to other places where he can find it. An index of this type, in the hands of a trained and experienced librarian, will in the end find what a customer wants to know, but it may require hours or even days of patient study and research to assemble all the information on an extensive subject.

Coming back now to the automatic electronic library, we find that the problem is entirely different. Here there is no necessity to arrange documents on shelves, nor do the subdivisions of an index have to correspond to a shelf full of books. The electrecords in this type of library may be arranged in any order, for the information will be assembled instantly and brought to the customer's television screen at the speed of electricity, no matter where it is located. All that is necessary is that each electrecord be associated with the correct dial code, so that the proper connections can be made by the automatic switchboard.

The index needs only to guide the customer's finger up and down the thirty columns of code buttons on a control panel. If he pushes the right ones, all the information corresponding to the punched code will be produced. In other words, the index must associate documents with code numbers—and not with shelves or bins, as heretofore. The subdivisions of the index need not be exclusive, but may overlap as much as desired, since they are no longer used as a means of identifying a book with a single shelf out of thousands of shelves. Instead, each document, or its electrecord, carries a code number corresponding to each of the various subjects it deals with, and the document can be found with equal ease by dialing any one of these various codes. We may therefore divide and subdivide our index according to all the various customer interests and subordinate interests and assign a block of code numbers to each of these interests, regardless of how much the subjects under various interests may overlap.

Now the index will look much different. Starting with the entire field of interest to be served by the library, our several main divisions will represent the various customer interests to be served by the library. For a military library these might include:

Sciences
Technologies and Associated Equipment
Manufacture
Characteristics of Materials
Effect of Natural Environment
Military Operations
Operation and Care of Equipment

Each of the customer groups represented is interested in information on all types of military equipment and activities, but each of them wants the information in the library arranged differently. Now each of these customer interests is subdivided into several main parts: sciences into the various fields of science; technologies and equipment into the specific technologies and general types of equipment; manufacture into various manufacturing processes; characteristics of materials into the particular characteristics to be measured; effect of environment into the various factors that affect men and machines; military operations into the various phases; operation and care of equipment into the various phases of installation, mechanical operation, and repair and maintenance of weapons, machines, and equipment.

Again, divide each of these subdivisions into the several special customer interests concerned. For example "Guns," under "Technologies and Equipment" would include several customer interests. One customer would be interested in various parts of guns such as mounts, barrels, and breech mechanisms. Another would be interested in grouping information according to sizes and calibers of guns. Still another would want groups according to type of gun: small arms, recoilless, cannon, etc. Still another would be interested in an arrangement by mobility: portable, horse-drawn, tractor-drawn, self-propelled, railway, etc.

To sum up: We divide the whole field of interest into general customer interests, and these into subordinate divisions, and these again into special customer interests, and these again into subdivisions, and so on. To each customer interest and subdivision we assign a block of code numbers. The resulting code index will look like this:

FIELD OF INTEREST

General *Customer Interest*

Division

Sp. *Customer Interest*	Sp. *Customer Interest*
Subdivision	Subdivision
"	"
"	"

Division

Sp. *Customer Interest*	Sp. *Customer Interest*
Subdivision	Subdivision
"	"
"	"

General *Customer Interest*

Division

Sp. *Customer Interest*	Sp. *Customer Interest*
Subdivision	Subdivision
"	"
"	"

Division

Sp. *Customer Interest*	Sp. *Customer Interest*
Subdivision	Subdivision
"	"
"	"

Each document will be coded under *all* appropriate customer interests but under only *one* division under each customer interest, and under only *one* subdivision of each special customer interest. Since the divisions of a customer interest may overlap in subject matter, we can simplify the process of coding and finding information by adopting a simple arbitrary rule of procedure: In coding, as well as in finding material, we will read each list of divisions or subdivisions from top to bottom and will code a particular piece of information under the first division which includes it, regardless of whether it would also be included under another division farther down the list. Since both the coder and, later, the customer will follow the same identical procedure, this will cause no confusion but will, in fact, make the customer's task easier and much surer than it usually is. He has to look in only *one* place, instead of looking under several overlapping divisions, any one of which might contain the information.

Perhaps the advantages of such a "multiple viewpoint" index are not at once apparent but they are nonetheless great. Essentially they are:

Ease and certainty of finding material. The customer does not have to understand or use a complex cross-reference system or card index in order to find all the information he wants under various different subjects. Instead, he merely reads down the index to the appropriate customer interest, then to the first appropriate division, then to the special interest, then to the first appropriate subdivision that includes the subject he wants. By dialing the code number of this final subdivision, he will obtain *all* the information he desires.

Condensed size of the index itself. This results from the fact that all the divisions and subdivisions under one customer interest act also as further divisions and subdivisions under all other customer interests. For example, by dialing the correct code for "Machine Guns" under "Technologies and Equipment," the code for "Lubrication" under "Care and Operation," the code for "Minus 50°" under "Effect of Natural Environment," and the code for "Air Operations" under "Military Operations," a customer would obtain all the information—and *only* that information—which deals with "The Lubrication of Aircraft Machine Guns at Temperatures of 50° below Zero." Thus, extensive division and subdivision of each field of customer interest are unnecessary, since it may be further subdivided as far as desired by coding additional divisions under other customer interests. A relatively small index provides for an almost unlimited variety of code combinations under which information may be obtained.

The combination of these advantages indicates that a suitable index, usable by a customer without special training, and covering all customer interests over the entire field of knowledge, could be condensed into a single volume. Such an index, although not suitable for a conventional bookshelf library, would be an absolute necessity for the automatic electronic library of the future, and would be useful now for a library possessing machines for rapid mechanical searching of index files.

A military technical index using these principles has been developed by the Department of the Army General Staff and is now undergoing tests. With further development and perfection it should

provide J. Doakes of 1980 with his Pocket Index to Knowledge.

Books without Cost

Added together, the electrecord, the autolibrarian, and the pocket index solve the problem of the automatic memory and bring the world's knowledge to the armchair of the average man. They do not, however, take the place of books. Although the customer of Knowledge Incorporated may conjure up any desired information at the crook of a finger, and review it on his television screen, he still needs to obtain printed copies of selected material before he can study it thoroughly and digest it. To take time for this while the television receiver is connected, long distance, to an automatic library, would cost entirely too much, and, besides, the customer sometimes wants to carry information with him to other places outside his library and could hardly take along a television receiver. Unless he can obtain printed copies of all the information he wants, and obtain them promptly, much of the advantage of the automatic memory is lost. The effect of having an automatic memory in the average man's possession will be to vastly increase rather than decrease the demand for books of all types. This means, in short, that the library must be prepared to furnish *immediately* to its many customers printed copies of every book they want. Considering that a library seldom has more than two or three copies of any book or report on hand, with customers numbering many thousands, the task will not be an easy one.

One answer to the problem would be for the library to print or buy up and store on the shelves enough extra copies of every book so that all the customers who wanted the same book at the same time could each borrow one and still leave a few copies for use in the library. This might please the customer, but would be extremely unprofitable, if not impossible, for the library. Multiplying the number of books would mean increasing the size of the library and the building it occupies by the same number of times. This, plus the cost of the books themselves and salaries for a larger library staff, would add up to a staggering total. The return from the investment would be small, for the bulk of the books would molder on the shelves 90 per cent of the time, and only occasionally would a sudden demand for particular books justify having extra copies of them.

Another answer would be to have no extra copies on the shelves but to have a printing plant in or near the library capable of printing additional copies rapidly, to lend or sell to the customer on demand. This, too, would be uneconomical, for the number of requests would be small on most days, and yet the plant would have to be big enough to take care of peak loads on days when the whole library was crowded with customers and swamped with requests.

Compromise, as usual, points the way: Put enough copies on the shelf to take care of the average customer requirements and provide a small reproduction plant to produce additional copies of particular documents on particular days when the demand exceeds the shelf supply. This is a grand theory. In practice, however, the customer will have to pay for the printing of the additional copies over and above the number stored on the shelves. These extra copies cannot be issued to the customer on loan, for the library has no place to store them when (and if) they are returned. There is no escaping the fact that, if all customers are to have copies of all the information they request promptly on demand, they will have to buy it for cold cash.

Exactly here is the crux of the problem, for few customers can afford to buy outright copies of every book they need for temporary use. If the ideal of providing the average man with all the printed information he requires at all times is to be achieved it can be done in only one way—by reducing printing cost to a very small fraction of what it now is. Microfilm appears to be a solution to the need for cheap copies of books and documents. It is not. True enough, it provides a suitable means of making a few cheap copies of documents for a few special customers, but for general use it is not adequate.

In plain terms, the ordinary customer does not want to be bothered with microfilm, figuring, rightly, that it is more trouble than it is worth. He wants information to come to him at his desk instead of his having to leave his desk and go to a microfilm projector every time he wants to scan, study, or refer to a document. He wants to lean back and put his feet on the desk, or sit in any desired position while reading or studying, instead of having to sit up like a ramrod in a fixed position to stare at an immovable projector screen. He wants information in convenient book or notebook form of standard size, so it will be easy to refer to and keep track of instead of having dozens of microfilm strips in pillbox-sized containers scattered on his desk. He wants to carry it along to another room or another building without having to carry along the projector. Above all, he does not want to have to unroll a film strip, feed it into a projector, hunt through the pages one by one, and

then reroll and replace it in its box every time he has to refer to a particular passage or look up a formula. In the end, his time is more valuable than the money he saves by buying the microfilm, and so he has the film enlarged to a standard size photostatic print—which costs him more than the regular book would have in the first place.

A modified version of microfilm is the microcard, which consists of a 3″ x 5″ file card with printed material microprinted on it instead of being microprinted on a film strip. Microcards are more convenient to file and handle than microfilm strips, but they still retain most of the objectionable features. Microfilms and microcards, although good for special use in archives, in business records, and in the library itself, offer no solution to the problem of giving the average man inexpensive books and printed documents in a convenient form that he can use outside the library in everyday life.

There is, however, a workable solution to this problem arrived at by a simpler and more direct approach. By the standard offset printing process it is possible to print, in miniature, as many as forty-nine page images on each side of a standard letter-size sheet of paper. In this method of printing, a page is first photographed, producing a film negative. From this negative, by a special process, a page image is etched onto a sensitized zinc plate. The etched plate is then fastened to the roller of a standard offset printing press, which then will print any desired number of copies on paper. In order to print in miniature it is necessary only to photograph the desired number of pages in miniature on a single sheet of film of the usual page size. The remainder of the process is identical. If twenty-five miniature-page images are printed in this manner on each standard-size page of a book, it is plain that the amount of film required, the number of zinc plates used, and the time required to turn out a given number of copies on the press, are all reduced to one twenty-fifth of the usual requirements. Some of the costs, such as setting up the press to do the job, remain fixed, however, so that the actual cost of printing a book or report in miniature with twenty-five page images on each standard-size page, is about twenty times less than for full-size printing. A book normally selling for two dollars would cost only ten cents if printed in this way. The catch is that the final product—the miniature print itself—has to suit the customer and overcome his objections to the use of microfilm. Otherwise, he will refuse to use this also, and will have it blown back up to full size, with a resulting increase, instead of decrease, in cost.

The main requirement is that it must be easy to read. Miniature print does not have to be unrolled and rolled and fed into any sort of bulky, awkward, and expensive reading machine. At reductions in size up to four or five times, it can be scanned readily with an ordinary reading glass, which has a magnification of two to three times. The Copeland reading device, recently developed for this purpose, provides a simple, inexpensive means of reading miniature print. This device magnifies a page image approximately four times by the use of a reflecting concave mirror, in place of the magnifying glass or lens commonly used in such devices. The concave mirror and another special mirror arrangement are contained in a small box a few inches square, containing windows of the same size as the miniature page image on two of its sides. The reading box is placed on the paper with one window over the page image to be read. By looking into the other window from eight to ten inches away, the user sees a magnified image of the page. The entire magnified page is seen clearly, without distortion, and may be read with normal ease in a lighted room and without eyestrain. Use of the concave mirror in place of a lens gives greater magnifying power and avoids distortion over a wider field of view than can otherwise be obtained with lenses. It is much less expensive than a system of lenses would be to accomplish the same purpose. A reading device of this type is cheap enough for every customer to own, and small enough to be carried with the customer and used at his desk or wherever he may wish. While reading the user can relax in any desired position. This overcomes the greatest objection to microfilm and microcards.

Other than the reading problem, miniature print overcomes all the other objections to microfilm and provides, in addition, advantages over both microfilm and normal-sized books. It comes in normal book-sized sheets or pamphlets that require no special filing or storage arrangements. It reduces storage space many times. A single loose-leaf binder containing five hundred sheets with twenty-five miniature pages printed on each side of each sheet will hold 25,000 pages of printed material. The same number of books on microfilm, averaging five hundred pages to the book, would require fifty separate microfilm strips contained in fifty film capsules, each as large as a can of shoe polish.

A library could stock ten to twenty extra copies of every document on its shelves in miniature print at small additional cost in storage space and at a reasonable cost. A central printing plant could supply a large number of scattered libraries with ten to twenty copies of each document and could

replenish these stocks rapidly on demand either by printing additional stocks or by making individual photocopies from the original film negatives.

Certainly, every customer would prefer to receive his information from the library in comfortable, solid, normal-sized print. But if he wants *all* the information he needs *when* he needs it, he can not afford to foot the bill. By using miniature print, on the other hand, he can have what he wants when he wants it and can afford to pay the price. In that way every man could have his own private library and could store it on a few shelves.

Under these conditions Knowledge Incorporated could dispense unlimited amounts of printed knowledge to its customers, on demand. Obviously, the bookkeeping expense involved in collecting the cost of individual miniature documents from individual customers would be as great as or greater than the cost of the document itself. The economical thing to do would be to keep no record of individual transactions, but to bill a service charge to all customers on a monthly per capita basis to cover the operating cost of distribution.

In effect, then, the customer of the automatic library of 1980 can not only have knowledge unlimited, but also books without cost.

The Real Arsenal

Up through the ages men have successfully crossed several great frontiers of knowledge and understanding. In succession, the development of spoken language, written language, the printing press, and modern communications have brought us further from the helpless and ignorant cave man.

Tools are shaping now to open yet another frontier of progress. With the automatic library and a free flow of printed information, every man can eventually have an automatic memory of unlimited scope, with the entire knowledge of the world at his doorstep. Instead of merely accepting or rejecting whatever a few experts see fit to place before him, he may himself choose the problems he thinks important and find the answers to them at his finger tips.

In these tools and across this frontier are to be found the real arsenals of individual freedom and democracy. A bomb destroys slave and free alike, without partiality or prejudice, but only a government of free men can trust all its citizens with complete knowledge and understanding and profit by the full genius and productive power of them all.

On the Importance of the Cultivation of Science

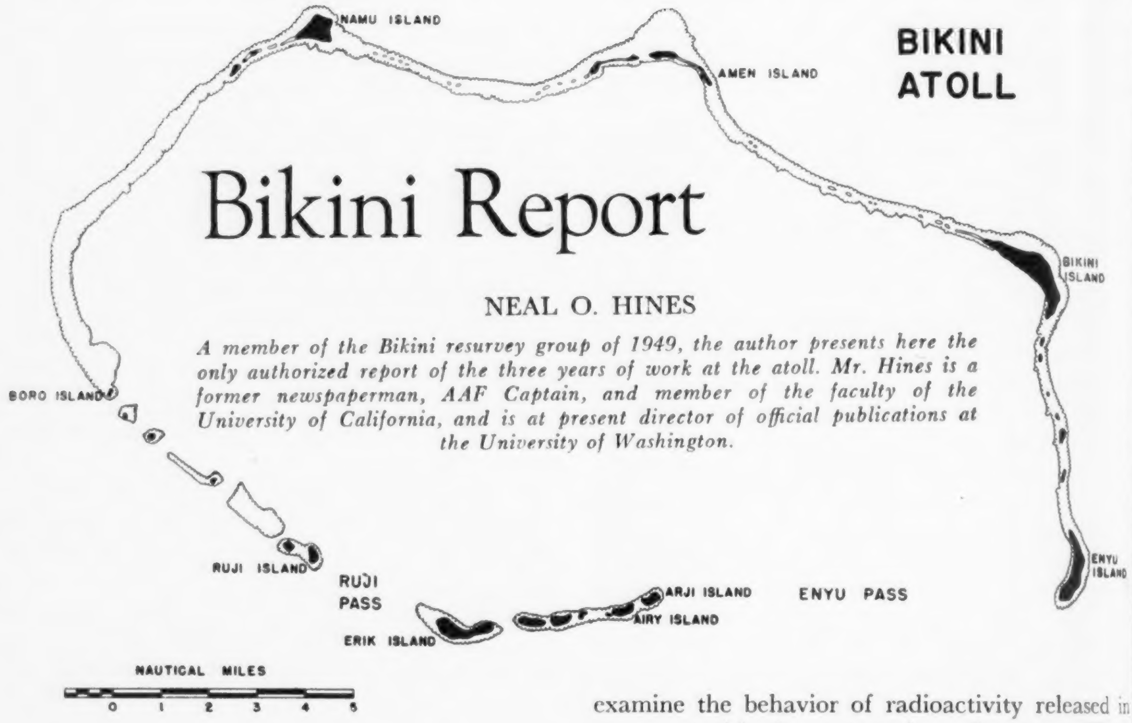
It is a fundamental principle of political economy that the physical state of man can only be ameliorated by means of labor, or, in other words, by the transformation of matter from a crude to an artificial condition. But this cannot be effected, except by expending what is called *power* or energy. In ancient times, almost the exclusive source of this energy was muscular force, derived from compulsory human labor; and all the monuments and objects that have been left to us, as marks of ancient civilization, are the results of organized systems of slavery. The rock-sculptures of Elephanta, the Pyramids of Egypt, and the temples of Greece, were all the result of the labor of slaves, directed by the minds of freemen. It is said that a hundred thousand slaves were employed at one time in the construction of the Pyramids of Egypt; one hundred and twenty thousand were engaged in hewing the obelisks of Thebes, and an equal number in digging the ancient canal which joined the Nile and the Red Sea. These slaves were treated as beasts of burden, or as mere machines, of which Athens, in her palmy days, had four hundred thousand, with but *twenty thousand* freemen.

Now, we owe the abolition of this condition of humanity, in the higher civilized nations of the world at the present day, to the study of the laws of the operations of Nature. By a knowledge of these laws the energies of the elements of Nature are substituted for human labor, and by this substitution mankind is not only relieved from brute-labor, but also given control of energies which enable him to produce effects which could only result from the muscular power of beings of a superior order. It may be shown by a simple calculation that about fifteen tons of anthracite coal burned in the furnace of one of our best steam-engines exerts an energy equal to that of an able-bodied slave, working ten hours a day for thirty years of his active life. It is this substitution of the energies of Nature for the power of human muscle that, as we have said, has abolished slavery and elevated humanity to a higher plane than was ever dreamed of by the wisest sages of ancient times. To illustrate this, a few examples will suffice. As one of these, we may refer to the progress of the arts of locomotion, and the means which science has afforded for the instantaneous interchange of thought between men in the most distant parts of the earth; as another, to the production of clothing fabrics, in which a single individual, directing the energies of an engine of one-man power, is capable of doing three thousand times the work of an ordinary weaver. As a third example, we may point to the art of printing by means of the steam-press, in which a single man will make more copies in a given time of a composition, than a million of ancient transcribers could do. Science is every day creating new arts, and modifying and improving the processes of old ones. We are skeptical as regards the value of lost arts. It is true there are arts which have fallen into disuse, and others which depend upon the skill and patience of the individual, but none which rests on any lost secret of Nature which science cannot restore.—Joseph Henry. *Pop. Sci. Monthly,* 2, 642 (1873).

Bikini Report

NEAL O. HINES

A member of the Bikini resurvey group of 1949, the author presents here the only authorized report of the three years of work at the atoll. Mr. Hines is a former newspaperman, AAF Captain, and member of the faculty of the University of California, and is at present director of official publications at the University of Washington.



WHEN Joint Task Force One came home in 1946, Bikini Atoll was a place unlike any other on earth. A tiny fleck of coral that had been virtually untouched by the sweep of the Pacific war, Bikini had been subjected by Operation Crossroads not only to the force of two atomic explosions, but to an unparalleled concentration of scientific, official, and public attention.

When Crossroads was over there were, of course, decisions to be made about Bikini. Ultimate decisions were impossible. Immediate decisions could not be made until the military and scientific people had examined their notes on the fourth and fifth of the earliest explosions of atomic bombs. Work had to be continued in the laboratories in the United States. Time was needed to sift out the conclusions.

Now, nearly five years later, certain matters still are under examination. But Bikini has moved far beyond those related to the immediate effects of atomic blast. Bikini is a place where, for the only time in history, scientists have been permitted to examine the behavior of radioactivity released in great quantities in an aquatic environment. There is little of the Crossroads radioactivity remaining now, although the traces, spread over the atoll, still are easily detectable. But only at Bikini have the conditions of underwater explosion been tested, and only at Bikini can the long-term consequences be explored.

Outline drawing above, prepared by Frank G. Lowman, research assistant in the Applied Fisheries Laboratory, shows the general shape of Bikini Atoll, the positions of the major islands, and the location of Ruji Pass and Enyu Pass, mentioned in the text.

For four years Bikini has been preserved as a research area, unoccupied, but visited regularly by members of expeditions sent there by the Atomic Energy Commission to watch Bikini's effort to eliminate the radioactivity placed in its lagoon and in its biological system by the underwater bomb test of Baker Day, July 25, 1946. The simple fact of Bikini is that bits of the radioactivity deposited by an atomic explosion of 1946 still can be found within the pulsing life of a Pacific atoll.

The Bikini case can be presented only in an interim report, but the story is worth telling because it concerns the ways that radioactivity has been held within the atoll by concentration and reconcentration in the tissues of living things. The story is less concerned with the amounts of radioactivity, which are small, than with where they go and what they do. It is the pattern of absorption, as well as its extent, that is important. That story belongs to the biologist.

The men who have returned to Bikini go there

as they would go to any friendly and familiar spot, one that holds much to interest them. They see at Bikini only the matchless opportunity to study the movement, through the food chains and organic systems of an aquatic environment, of radioactive isotopes formed in the fission of the Baker bomb. They know where they have found Bikini's radioactivity and, within certain limits, in what amounts. They believe its courses and its effects must be watched and assayed before the books can be closed on Crossroads.

II

Of all the atolls in the world, perhaps, Bikini alone would be identifiable on sight by the shipwrecked wanderer. Its camera towers, long unused but still thrusting their houses high against the horizon, mark it unmistakably. The small beached vessels, the scraps of rope and metal on the sands, the GI huts whose canvas roofs are sagging and rotting, the vine-covered frames of motor vehicles in the old Seabee area, the empty instrument revetments echoing to the strange footstep, the Coca-Cola bottles and rusty beer cans scattered among the dead palm fronds and sprouting coconuts—all these are the special treasures Bikini still holds beyond the reach of the Pacific. Bikini is a mixture of moods. It has the brilliant and beautiful charm of the lonely tropical island, the spell of the house long unoccupied, the tugging interest of the old battlefield, the touch of great events. Only the pounding of the breakers on the wide reefs and the cries of the fairy and noddy terns, wheeling over the green brush or strafing the long beaches, interrupt the silence that is almost primeval. But three miles off Bikini Island, in 180 feet of water, are the hulls of the U.S.S. *Saratoga* and *Arkansas,* the Japanese battleship *Nagato,* and the other ships that did not survive atomic explosion. Big iron buoys bounce in the water over the places where the ships rest, and long surface slicks, which can be seen from the air, show where the oil still rises from the dead target vessels.

The scientists who have been visiting Bikini since 1946 have come to know it well. They have prowled among the towers and buildings, they have carried Geiger counters for miles along the strips of sand, and they have spent days around the coral heads, spreading poison on the water and diving for the specimens of fish in whose tissues they will find, as often as not, small concentrations of the dosage of radioactivity placed in the lagoon so many months before.

On the charts of the Pacific, Bikini Atoll is a dot among the many dots that comprise the Radak and Ralik—the eastern and western—chains of the Marshall Islands. Bikini is not a dot, of course. It is an oval saucer twenty-three miles long, its rim marked by the green masses of ten major islands and its reefs perpetually edged by a lacework of breakers bursting and surging through intricate patterns of coral. Because Bikini is a saucer, with the shape characteristic of the coral atoll, it was an ideal arena for atomic tests, but Bikini was selected because, among other reasons, its southeast rim dips to form an entrance called Enyu Channel, a passage wide and deep enough to accommodate the shipping that was to be brought there by Task Force One.

Operation Crossroads was a military experiment, planned as a series of observations of the effects of atomic blast and released radiation. Joint Task Force One took to the Northern Marshalls 242 ships, 156 airplanes, 750 cameras, 25,000 radiation recorders, and some 42,000 military and scientific personnel and observers. Bikini, in the spring of 1946, was transformed. Steel barges, moved to the beaches, made docks for the landing of the thousands of men who jammed the atoll. The twelve 75-foot camera towers and the many huts and shops of the shore installations went up. Planes shuttled between Bikini and supporting areas. Bikini lagoon was churned by the movement of small craft, and in the target area was assembled the great fleet of brave old battlewagons and heroic survivors of the war that had so recently ended.

The first bomb, the air drop, was detonated above the target fleet on Able Day, July 1, 1946. The second was exploded beneath the waters of the lagoon in Test Baker on July 25. A third bomb was to have been used in a deep-water explosion to be designated Test Charlie, but that test was never held. Since the major interest was in explosion, the primary effort necessarily was directed at measurement of the immediate and external effects of impact and radiation on ships, equipment, and on the atoll itself.

In 1946 it still was not realized that Bikini offered opportunity for continued study of the remote and residual effects of atomic explosion. There was plenty of interest in, and concern about, radiation. Technical staffs made thoroughly adequate preparations for monitoring, plotting, and measuring radioactivity, but the emphasis was on operational safety and on the expectable results of dumping vast quantities of radioactive materials in a relatively restricted area. The Oceanographic Group had made studies of lagoon currents, so that the post-blast up-wellings of water and suspended minerals could be anticipated. There were

This is the east rim of Bikini Atoll, looking south toward Enyu Island. Little Ion Island is in the foreground. The camera towers can be seen against the dark mass of palm trees on Enyu, and barely discernible at the near tip of Enyu, on the lagoon side, is the wreck of the LSM 816, one of the smaller Crossroads target vessels. Enyu Channel is to the right of the photograph.

preparations for experiments in decontamination procedures. There was a great curiosity about the effects of external radiation on creatures in the waters and on the test animals aboard ships of the target fleet. But there was little thought of Crossroads as the starting point for long-term research in radiobiology or of investigations in the field of the possible effects on living things of absorbed fission products. The whole matter was too new, and too many other questions were involved. The problem was not really clear to the biologists, who should have been most interested.

The total of radioactivity present at the microsecond of atomic explosion was equal, according to estimate, to hundreds of pounds of radium. When the explosion occurred under water, it was the first case (as it still is the only case) in which an atomic bomb was used in such a way that fission products would be mixed with water and thus returned in great measure to the area of detonation. Because the explosion was under water, the fireball appeared as a great bubble that burst from the surface of the lagoon. Millions of tons of water, mud, and shipping erupted into a pillar that stood for many seconds above Bikini, its head more than a mile high and its column containing, near the base, some of the big ships of the target fleet, up-ended by the blast and lifted hundreds of feet above the surface. When the weight of the geyser came crashing back into the lagoon, the target area became a maelstrom holding tremendous quantities of radioactive debris. A shallow basin half a mile wide was formed when the force of the blast scooped coral and sludge from the bottom of the lagoon, and this basin was found later to be filled with 500,000 tons of mud which was—and still is—moderately radioactive.

The situation at Bikini after each of the explosions was one of anticipated hazard, but the Radioactivity Group had been created to handle

the immediate problems. Emissions of activity in the air and in the water about the target area were plotted by radiological teams in planes and picket boats, and if the danger was great, it also was of relatively short duration. The detonation that manufactures radioactive materials also scatters them, and the short-lived high-impact radiations are beginning to be dissipated in microseconds after the explosion occurs. That is what happened on Baker Day, but the underwater explosion returned more of the fission products to the waters and to the sludge of the target area.

Radioactivity is a natural phenomenon, a factor in the normal conditions surrounding all life on earth. The radioactivity at Bikini is of the same quality as that which forms the "background" of activity picked up by any Geiger counter, the same as the traces of radium, uranium, or potassium found in soil, in water, in food. But atomic explosion creates superamounts of this activity, and these additional amounts will be acknowledged (when they are not too great for measurement) by additional numbers of clicks or pulses in the Geiger counter, which simply is registering, incompletely, the frequency of atomic disintegrations, or emissions of particles by radiation materials. In the days after Crossroads these emissions of activity occurred at frequencies of millions of counts per second. For a week after Baker Day the radiological teams patrolled Bikini lagoon, checking and plotting the swirling and shifting areas of activity in the water. A year after the blast, however, radioactivity had subsided to such an extent that, by contrast, Bikini seemed almost free. But Bikini was not free. It is not free yet, even though the quantities of activity may be expressed, in many instances, as multiples of the normal background.

The research at Bikini has been only secondarily concerned with miscellaneous readings of radioactivity as factors in some incalculable total residue. More important are the questions of where the residues of activity have been distributed, why they have stayed at Bikini, and what effects, if any, they are having at specific places. In 1949, three years after Crossroads, the clicks of the Geiger counters carried into the field indicated the presence of extra amounts of long-lived β-γ, but when specimens of animal or plant tissue are subjected to the more sensitive counts of laboratory instruments it is possible also for the biologist to obtain counts of α radiation. Alpha, like most β, can exert no effect on tissue unless it gains access to the tissue itself, and the traces of α at Bikini are so difficult to detect, so difficult to pick up under the more penetrating β-γ emissions, that the problem only now is beginning to be approached in the course of the Bikini research. But the α-question must be understood in its own terms, because the Bikini work has centered about the possible effects of radiation absorbed, over long periods of time, by organisms exposed to an irradiated—to even a mildly irradiated—environment.

Bikini thus has been safe for years for scientific visits (and for any such use as, say, military operations), but it holds within its organic system traces of radioactivity whose potential can only be assayed by repeated samplings at the places, whether in plant or in animal tissue, where it is most likely to concentrate. The total of radioactivity originally placed in the target area was reduced in the first month to a fraction of its original potency, but the long-lived residues still persist, and bits of activity have been spread constantly from the target area to other parts of the atoll.

The surveys of Bikini land masses show the scattering of these traces, but they also show where biological processes—the processes of growth, diet, movement, reproduction—have placed concentrations of activity. The conditions vary from island to island, from Enyu Island, east of Enyu Channel, to Bikini Island, northeast of the target area, to Amen and Namu, on the north rim of the atoll, and to Erik, Boro, and others to the west and south, but the general pattern of the readings will be the same. The sands of the beaches may show, on the Geigers, only a background reading, about 35 counts per minute on the field instruments. The counts may rise to two or three times background in the areas of green vegetation, higher when the counter is placed near the dried plant life scattered on the ground (because emissions of activity are not absorbed as they are by the moisture in living plants), and still higher at or near the scraps of wreckage or patches of black oil scum found here and there on the coral. Activity will be found somewhere on each of the islands checked and, in many cases, on the reefs between. But, as will be noted later, concentrations of activity have appeared in areas where they were not expected, so that studies of these movements and their causes have been necessary.

Because instrumentation and research methods have been improved from year to year, the surveys have been directed increasingly at certain spots within the atoll and at certain problems that need specific attention. The surveys of the islands with the Geiger counters actually are the most superficial parts of the total measurement, serving only as checks on the general distribution of continuing activity. In 1948, for example, the survey of Enyu

In 1949 oil still was seeping to the surface of Bikini Lagoon from the target ships sunk during Operation Crossroads. This photo, made by Frank G. Lowman from a Navy PBY, shows the buoys (black dots) that mark the positions of the sunken ships.

Island showed that the activity on the sands of the lagoon side was at a normal background count. Green vegetation gave a reading of 250 counts per minute and dead vegetation 400, about eleven times background. But the beaches of Enyu held, as they still do, much drift material, such as scraps of canvas, truck tires, wooden grilles, boards, and pieces of rope. At the north end of the island, also, was the rusting hull of the LSM 816, one of the small ships of the target fleet, beached after Baker Day. The counts at these miscellaneous items, including those on or about the LSM, ranged from 3 to 1,700 times background. One spot of driftwood had a count of 21,000 per minute. A bit of wooden grille gave 6,500 counts. A life raft on the ocean side of the island produced a reading of 46,000, and a door mat from the LSM showed 60,000 counts. These samplings were made two years after Crossroads. The counts of 1949, slightly lower, had followed the normal decay pattern.

On Boro Island, to the southwest of the atoll, the 1948 survey showed that the green vegetation was at 80 counts per minute and dead vegetation at 500 counts. Oil scum on the coral counted about 4,000, and one plywood trough, apparently torn from a target vessel, counted 23,000. Readings such as these were reproduced in many places in 1948 and 1949.

The important land samplings, of course, are those on the sands or in the plant forms, in the living plants or in the mattings of dried fronds and leaves. Radioactive materials, feeding from the bottom of the lagoon at the target area, have been carried about and deposited in certain spots by some elemental machinery whose workings have provided some of the most fascinating problems of the research.

Because radioactivity persists, its presence can be noted and measured. It can be traced through the food chains of biotic systems. The biologist, by taking enough samples at selected points on the scale of living things, has been able to study the absorption, transfer, or movement of this radiation as if he were performing a nutritional experiment in his laboratory. He can, by careful measurements, determine how much radiation has been absorbed by any single specimen, plant or animal, and he can note where the radiation has been deposited in the tissues of the plant or in the tissues or organs of the animal—in the skin, muscle, bone, liver, or kidney. By knowing how the specimen feeds, he can discover how it took radiation into its system. Finally, if the biologist can determine the tolerance to radiation of the various forms, he can see whether any specimen has absorbed amounts that are harmful. He must approach the problem knowing that radiation has no beneficial effects and that, if any living thing absorbs radiation in sufficient amounts, the effect will be damaging to some degree. His job is to find out where the damaging effects begin—whether the absorption of radioactivity has produced overamounts that are harmful to plants or animals and whether there will be effects in succeeding generations of these species.

III

Bikini has been surveyed at least once each year since Crossroads. Scientists thought each survey might be the last, but the Bikini problems, like the traces of radioactivity, persisted. The first survey, in 1947, was a Crossroads post-mortem encompassing every aspect of the effects still examinable a year after the bomb tests. It was directed by the Navy and it was full-scale. About fifty scientists, transported to the Marshalls aboard the U.S.S. *Chilton*, a Crossroads laboratory ship, worked over Bikini for six weeks, reexamining, remeasuring, rephotographing, and rechecking. It was important to take another look at the bomb damage itself and it was important to get readings of the residues of radioactivity that might be expected to cling to objects that had been involved in the tests. While Navy divers explored and photographed the hulks of the sunken target ships, and while mud and materials were dredged from

the bottom of the lagoon, the scientists examined the flora and fauna, studied the populations and individual specimens of fish and other aquatic species, and analyzed thousands of samples of organs and tissues of life forms taken from the atoll.

The 1947 survey measured Bikini with appropriate thoroughness. Except for the materials at the target area, where there still was considerable activity, the β-γ counts were found to be low. Bikini had lost its "danger" from external radiation, the highest counts seemed to be found in completely expectable places, the usual patterns of life were unaltered, and there were no examples of freaks or cancers or mutations in Bikini's living systems. The 1947 survey might have ended the Bikini research. It did not do so simply because there was some lingering doubt about those remaining spasms of radioactivity. There was just enough doubt to make an immediate decision seem unwise.

The scientists who thought Bikini should be looked at later included those who had been working since early in the war with the radiobiological research incident to development of the atomic bomb. They included Stafford Warren, who had headed, under the Manhattan Project, the office which soon would become the Division of Medicine and Biology of the Atomic Energy Commission. Interested in the Bikini question were biologists from a number of university laboratories, including the University of Washington's Applied Fisheries Laboratory, a contract unit in aquatic radiobiology.

The people of the Applied Fisheries Laboratory were biologists before they were radiobiologists. They participated in Crossroads as leaders of monitoring teams of the Radiological Safety Section, and in 1946 there had been a tendency to regard as almost comic the presence of fisheries men at bomb tests that many observers believed would decimate the fish populations of Bikini lagoon. But the Applied Fisheries Laboratory had won its place in the atomic program. The laboratory had been created as early as 1943 to study the effects of radiation on all types of aquatic organisms. The Office of Scientific Research and Development had needed an agency to check possible radioactive effluents from the plutonium plant operations at Hanford, Washington, and the University of Washington not only was near by, it had one of the few schools of fisheries in the world and, consequently, a pool of personnel familiar with research in aquatic biology.

The man who headed the laboratory was Lauren R. Donaldson, a young biologist and associate professor of fisheries, who had been at the University of Washington for fifteen years. He gathered together certain picked research workers and launched the radiation studies. When the end of the war brought the Crossroads tests, Donaldson and his colleagues were among the hundreds of specialists invited to participate.

The Applied Fisheries people did not disagree with the general findings of the 1947 survey. They simply began to see Bikini, in 1947, as a tracer laboratory. They were curious about what was becoming of the radioactive isotopes created by the explosion. They wondered if they were being moved from the bottom of the lagoon and rinsed out of Bikini by currents and tides. They wondered if organisms contaminated by radioactivity were selectively retaining some elements and excreting others. They had observed, for example, that measurable quantities of fission products were present in every part of the lagoon, but that the greatest activity was found north and east of the target area. They noted that radioactivity was found, in some quantity, in all species of fish sampled, in all areas where samples were collected, and in all types of fish tissue—muscle, skin, liver, and so on—submitted to analysis. The tabulations showed that the greatest amounts were in the organs of fish that live chiefly on algae, and that the highest counts were recorded in the livers of these miscellaneous specimens. They had found, in addition, that radioactivity in the invertebrates, such as snails, crabs, or sea cucumbers, generally was higher, in proportion to sample weight, than that encountered in fish and other vertebrates, and that counts in algae were higher than those in either vertebrates or invertebrates.

All this, to the biologists, was interesting, not because the counts of radioactivity were high or

This is the LSI 1091, the 1949 laboratory ship, anchored in Bikini lagoon 500 yards off Bikini Island. The worktables and the shower stalls (white canvas) can be seen slung outboard at the stern of the vessel.

low, but because the presence of radioactivity permitted them to outline theories about the behavior of radiation released in water. They had tentatively concluded that radioactivity was being held within the atoll by a process of transmission in the food chains—that radioactivity was being passed from the primary, radiation-resistant lower forms to the higher forms, where its dissipation was delayed and where it had unknown effects. Then one almost casual observation, made as the 1947 expedition was folding its gear for the trip home, led them to an idea that opened the door to research which has been conducted ever since.

While the *Chilton* was anchored at Bikini in 1947, the big wooden cradles used to support the picket boats on the decks of the vessel were unloaded and buoyed in the waters near the beach of Bikini Island. The cradles floated at the moorage from July 15 to August 18, and during that period certain fouling organisms grew on the wood. One growth, a marine hydroid, was especially prolific, and after the cradles were returned to the ship, the biologists gathered some of the material and made a reading of its radioactivity. The reading showed that the hydroid samples contained low, but easily measurable, overamounts of radiation. Since the growth had attached itself to the cradles after the expedition arrived, it was obvious that activity still was being carried about Bikini and deposited, by some relentless natural process, at previously uncontaminated places.

Two ideas immediately presented themselves. One was the idea of continuing circulation and concentration of radioactivity. The other was the idea that, because of the absorption of activity by minute forms of life, Bikini might be expected to retain radioactivity much longer than anyone had anticipated. In 1947 it still seemed logical to believe that water would cleanse Bikini. The water of the lagoon was known to have a half-life of twenty-eight days; that is, in each twenty-eight-day period half the lagoon water was replaced by water from the ocean. In the year after Crossroads the water had undergone thirteen half exchanges, and that constant outflow, it was thought, would dispose of the radiation problem. But the lesson of the hydroid, and the conclusion to be drawn from the studies of other specimens, was that biotic absorption might make dissipation of radioactivity a much more gradual process. By 1949, when the water had undergone thirty-nine half exchanges, activity from the target area still was moving through Bikini's life cycles. Much of the energy had been washed away, of course, and much had exhausted itself and vanished in the normal course of decay. But the residues still were readily measurable, even in gross samplings in the field.

The clue provided by the hydroid also suggested a solution to another problem that had seemed especially puzzling. It was observed in 1947 that higher counts of radioactivity seemed to be obtained on the reefs to the north and east—between Amen and Bikini Islands and between Bikini and Enyu—three miles or so from the target area. This circumstance might not have been noteworthy except that it contradicted, in part, pre-Crossroads expectations. The winds of the Marshalls blow almost constantly from the east. It had been assumed in 1946 that the greatest quantities of fission materials would be found westward of the atoll, in the fall-out area downwind from the clouds of radioactive debris. By some freak chance the winds of Baker Day came from the south, so that when the fall-out occurred most of the radioactive products actually had been carried over the northeast rim of the atoll, between Amen and Bikini Islands. But within the atoll, a year later, the Geiger counters of the land surveys and the counts of animal and plant specimens indicated that larger amounts of activity were spread eastward—in the normal upwind direction from the point of explosion.

The biologists concluded that, if radioactivity were being moved about by living organisms in the water, the currents inside the lagoon were helping the movement. The surface waters move with the winds, from east to west, but the cycling currents below unquestionably were carrying microorganisms, many of them containing small quantities of activity from the target area. These organisms were being deposited by the subsurface currents in the protected reef formations to the east of the atoll, and thus the total accumulation of these deposits was producing higher readings on the counters. The extra amounts to the north actually were caused by the fall-out, those to the east by the slow process of up-welling.

It could only be concluded, further, that every living form was a possible contributor to this movement of radioactivity from one place to another. The microorganisms or the planktonic forms could be assumed to be basically responsible, but activity ingested slowly by other creatures certainly was being concentrated and moved about in similar ways and transferred from organism to organism in the unremitting and rapacious contest for food.

To use a simplified example, a theoretical Bikini fish might live out a lifetime touched only slightly or not at all by whatever radioactive materials came to his special area of action. But if he nibbled at irradiated substances on coral reefs, or if he fed

on the layers of phytoplankton lying at the edges of the cycling currents, he might begin to participate in the radiobiological process. Radioactive materials, entering his body with food, would be deposited in his tissues just as normal salts are handled in the metabolic system. If the accumulation in his organs became sufficiently great he would sicken and, weakened, would be consumed immediately by other fish, who in turn would store some of the activity. If he lived out a normal life span, his death, when it came, would free the radioactivity to continue its circulation and reconcentration.

These ideas were examined and tested in 1948 and 1949. In 1948 the Applied Fisheries workers repeated their experiments with the picket boat cradles, leaving wooden frames in the water and making counts of the freshly deposited hydroids thus collected. In two weeks the growth used for sampling had concentrated an activity equivalent to 24,500 counts per minute per gram of tissue

One of the important areas not yet completely explored is that of the absorption of activity by land vegetation—grass, the coconut palm, the pandanus, the papaya, and other plants. The field counters will indicate low activity in both green and dead plants on many parts of the atoll. As late as 1949 the Geiger pulses rose erratically as the instruments were held at the dried foliage on the ground or were moved in the tangles of brush inland. The more specific counts of 1949 plant tissue samples still are not available, but in 1948 the field counts of dead vegetation were ranging up to 750 per minute—about twenty times background—on Boro Island, eighteen miles to the west of the target area, and to about the same levels on Enyu Island, five miles to the southeast. Members of the surveys have been convinced that there is an absorption of activity by plants, but it is obvious, too, that some of the continuing activity is caused by surface contamination in the fall-out of atomic explosion. Boro Island, which lay in the path of the Able Day fall-out, has been presumed to present cases of surface contamination and tissue absorption; but there was no fall-out over Enyu, and activity in plants there seems almost certain to be activity produced by materials carried to the island by water and picked up by plant roots reaching into the porous coral base.

Since the late summer of 1946, no plant or animal specimen taken from Bikini has shown ill effects of radioactivity. But ill effects are not always apparent, because they may consist only of lack of normal development or be indistinguishable from the slight differences in structure found everywhere in nature. The biologists know only that radioactivity in any amount produces some deleterious effect, whether it is observable or not. They do not know whether the low level of activity at Bikini has some as yet unprobed potential. But they believe that in a world that is rocketing into an atomic future no scrap of evidence must be dropped, no avenue of investigation overlooked.

IV

It is a remarkable thing that bits of Baker bomb radioactivity still can be found in so many places in an oceanic area constantly whipped by wind and washed by rain and heavy seas. But it is only because the environment is oceanic that the matters of circulation and concentration have presented unique problems in the effort to understand the ultimate effects of atomic explosion.

The Applied Fisheries Laboratory, assigned to the Bikini research after the 1947 survey, has been the coordinating agency that has taken to the Pacific small staffs of scientists. Members of the permanent staff include Allyn H. Seymour, assistant director, plankton research; Arthur D. Welander, ichthyologist; Kelshaw Bonham, invertebrate research; Frank G. Lowman, genetics; and John Koch, instrumentation. Men representing other universities and research areas have included Asher A. White, of the University of Minnesota, and Frederick H. Rodenbaugh, of San Francisco, radiology; Theodore Bullock and Edward Held, of the University of California at Los Angeles, and Spencer Tinker, curator of the University of Hawaii's Waikiki Aquarium, invertebrate research; George Hollenberg, of the University of Redlands, and Ralph Palumbo, of the University of Washington, algology; Clarence F. Pautzke, of the Washington State Game Department, general biology; and Orlin Biddulph, of Washington State College, and Harold St. John, of the University of Hawaii, botany.

The Bikini expeditions, moved to the Marshalls by Navy air and sea transportation, use Kwajalein as a base of operations for the surveys at Bikini and at Eniwetok, the 1948 bomb test area now added to the radiobiological program. Survey activities are conducted from a headquarters-laboratory ship provided by the Navy, an LSI rigged up for scientific purposes. At the stern of the vessel used in 1949 was a big pump, capable of bringing up 10,000 gallons of water an hour, with which the expedition collected samples of water and plankton from depths to 140 feet at the target area and at other selected points within the atoll.

Members of the survey parties make daily trips

Lauren R. Donaldson, director of the Applied Fisheries Laboratory, places a specimen in a collection sack during a fish-collecting trip in the lagoon.

to the major islands to collect specimens and to conduct the land surveys. Men and equipment are transported in small auxiliary landing craft to points just beyond the island breakers, and there the personnel and the gear—the Geiger counters, cameras, film, collection bags, knives, machetes, face masks, canteens, sunglasses, ropes, and a shotgun—are piled into 12-foot rubber life rafts for the final ride to the beaches over the long lines of breakers. In 1949 Enyu, Bikini, Amen, Namu, Boro, and Erik were used as check points and collection stations, with some activity readings and miscellaneous collections on the sand spits and reefs between.

The many species of fish are important to the studies because they form the bulk of the vertebrate animals available for sampling, but every other form is equally important. The expeditions each year have taken specimens of Bikini birds, the terns and the other less common inhabitants of the central Pacific atolls, and they have brought back tissues of the small concolorous rats that lurk in the grasses and burrows of the islands. No form of life is neglected, for each is a possible participant in the radiobiological process and each occupies a specific place in the biological sum of the atoll.

Specimens of algae and invertebrates are harvested principally in the shallow waters of the reefs or on the beaches at the water's edge. Plant samples, including those from the pandanus and the coconut palm, are whacked down with matchetes and stripped where they fall. Water and plankton are collected with the shipboard pump or by dragging plankton nets behind the small landing craft. Sludge from the bottom of the lagoon is dredged up in perforated metal containers, which bring to the surface shells, scraps of coral, metal, and all the odds and ends piled by nature and by atomic explosion into Bikini's saucer. Specimens of fish are caught in wire-mesh traps placed about the coral heads or, in the case of shark and tuna and other big specimens, with hook and line. But the greatest numbers of fish are gathered by men who, working in the surf and in the coral shallows, spread poison on the waters and then dive to bring up the stunned victims. Frequently they must work rapidly to get their specimens before the curious little black-tip sharks move in.

The study of radioactivity in plant and animal tissue is a procedure very different and more exacting than that involved in the surveys of activity on the islands. The counters used in the field are portable and are built for field conditions. They are β-γ counters that give readings of gross activity, but they have only a field-work sensitivity and are designed to tell only that certain numbers of emissions of β-γ penetrate the glass-enclosed ionization chamber. The field meters necessarily fail to record the emissions absorbed by moisture in the sample or by thickness of tissue. Sliding shields on the counter chambers make it possible to determine whether the readings are being caused chiefly by β or γ, but the counts noted on the field instruments may be multiplied many times when carefully detailed counts are made under laboratory conditions.

The final counts are made in the Applied Fisheries Laboratory itself. In 1949 hundreds of samples were preserved in deep-freeze lockers aboard the expedition's headquarters ship until they could be flown back to the University of Washington for examination. The work, accordingly, is divided into two phases: the surveys at Bikini, with the collection of specimens, and, later, the preparation and analysis of the hundreds of tissue samples, and the tabulation of amounts and types of radioactivity detectable in them. The field work can be accomplished in two weeks, but counting and checking and tabulating take many months.

Each of the samples submitted to count, whether it be a bit of coconut shell, a fragment of algae, or a piece of tissue from one of the fish, must first be reduced to ash, to eliminate moisture, which absorbs emissions, and to obtain material whose thickness can be controlled. A bit of tissue is placed on a 1.5-inch stainless steel plate, which is heated with hot plate and ultraviolet lamps until only the dry tissue remains. The plate, with the residue, then is placed in a muffle furnace, in which the temperature is increased gradually to 500° C.

When the plate is removed, it contains only a small heap of white dust, which may or may not have a determinable overamount of radioactivity. The problem, then, is to discover in each plate of dust whether radioactivity is present, the amount, and the type. Ultimately, when all samples have been ashed and counted, the Bikini workers may know that at a particular time activity of certain intensity was found in specific organs or tissues of living things collected at known places and having characteristic functions in the biology of Bikini.

Since the research necessarily involves study of the transfer of activity in the aquatic food chains, the collections of specimens must include, so far as hard work and luck will permit, most of the forms that are links in Bikini's biotic system. At the lower end of the chain are water and minerals; a step above are plankton and algae; further up are the Crustacea, such as crabs and other invertebrate forms, and the fish, which range in size up to sharks, barracuda, and jacks. In the oceanic food chain algae form the diet of the herbivores—parrot fish, signanids, surgeons, and blennies—and of certain of the omnivores—puffers and damsel fish. The herbivores are the prey of the reef-dwelling carnivores—lizard fish, snappers, and groupers—and these, in turn, are consumed by sharks and barracuda. Thus radioactivity originally absorbed by the radiation-resistant algae conceivably is passed, step by step, from the algae to the largest fish as one form preys on another. Almost incalculably complex factors might alter or divert this transfer or result, but the biologist, by sampling repeatedly at each of the levels of life, can hope to obtain some picture of the race between the normal decay of radioactivity and its progressive and cyclical absorption by species exposed to traces taken from the long-lived supply at Bikini's target area.

As early as 1947 it had been noted that tissues of the larger fish frequently produced counts higher than those of the reef fish. One striking demonstration of this occurred, quite by chance, in 1949. Four members of the survey team, to break the routine of work on the islands, took deep-sea gear and went fishing at dawn one morning near Ruji Pass, west of Erik Island to the southwest of the atoll. In two hours they had hauled into their LCVPs half a dozen groupers, barracuda, snappers, and mackerel (and the severed head of a giant tuna which was attacked and eaten by sharks before it could be brought into the boat). Following their invariable practice, the biologists stripped away the selected tissues and preserved them for laboratory count. Months later, when the samples of these Ruji fish were ashed, it was discovered that the livers of each had counts of activity higher than those of fish taken from the reefs and at least as high as the tissues of fish taken from the target area. Since Ruji is an outlet for Bikini waters, the fish may have spent a long time at the point of flow, picking up contaminated food materials. Or, since the big fish are rangers, it was considered possible that they had spent some time in the target area before moving on to Ruji Pass. Dr. Welander, the Applied Fisheries ichthyologist who has been studying Bikini fish since Crossroads, has suggested that the big fish, as the end products of the aquatic food chain, may be ingesting more radiation materials because they move about more freely and sample foods more widely. But there also is the chance that both the size of the fish and the depths of the waters in which they live are factors in their contamination. There is only the evidence of 1949 and previous years that the livers of the larger fish show greater concentrations of activity. Dr. Welander plans to make further studies, by groups, of herbivores and carnivores to try to discover if there are differences in their opportunities or tendencies to concentrate activity.

The tabulations of activity made under laboratory conditions are expressed in disintegrations per minute for a gram of wet tissue, the figure being merely a corrected count of β-emissions for a selected quantity of animal tissue before ashing. The Bikini aquatic samples ashed and counted after the 1949 expedition totaled more than 750, a number somewhat lower than that for 1948, but excluding, of course, all plant samples similarly processed. Of the 293 samples of fish tissue, 138, or 47 per cent, showed "significant" β-activity, ranging up to a maximum of 1,000 disintegrations per minute for a gram of tissue.

The sponges were tabulated separately from the other invertebrates because they have been found to present a special problem of adsorption. Sponges offer complicated surface structures, suggesting that they may play separate roles as accumulators of contamination. Of the 21 sponges studied in 1949, 16 showed significant activity and the disintegrations per minute rose to 3,000. Of the 356 invertebrates other than sponges, only 62 had counts considered important, but one of these contained activity of 5,300 disintegrations per minute.

The over-all figures represent only the samples counted after collections in all parts of the lagoon. They include, necessarily, all those samples in which no overamounts of activity were detected. If samples of fish, for example, were limited to those taken from the waters of the target area, about 98 per cent would show "significant" activ-

ity. Where activity was noted in fish, it was most frequently found in the spleen, liver, and viscera. There was little or no activity in bone or muscle.

The levels of activity are low at Bikini. But what does it mean when one invertebrate organism, a clam or a sea slug, can take into its tissue β-ray activity of 5,300 disintegrations per minute? In the roughest approximation, it means that a clam having *in each gram of its tissue* the energy associated with 5,300 disintegrations per minute would be approaching the maximal permissible tolerance dose for man. The example is purely hypothetical. The presumptions in such a case are too complex to be followed, but the fact remains that a small living thing, whose personal tolerance dose is unknown, had taken into itself by 1949 an amount of radioactivity that was neither low nor unimportant.

V

The key question of the Bikini research might be put thus: What has been the effect of one underwater atomic explosion at a place that should be inhabited by man? The answer, unfortunately, cannot be stated finally even yet.

Orlin Biddulph, professor of botany at Washington State College, marks coconut specimens in the shipboard laboratories. The coconuts were given special attention because of their importance in the native diet and economy.

There has been no "danger" at Bikini, as men think of danger, since the days immediately following Test Baker. But certain things have happened there, and all the repeated surveys and samplings have been parts of a continuing effort to find out what those happenings were. Although Bikini's radioactivity decayed and was washed away, and although it has disappeared little by little until its traces are very difficult to measure, the people who have visited Bikini certainly have learned a very great deal more about aquatic radiobiology than ever was possible before Crossroads. As scientists, they can be quite as happy with negative answers as with positive. At least they can feel that they are nearer the truth.

But, if the central question of Bikini still is unanswerable, there are, in fact, a number of answers that someday may be fitted together. All of them appear against the knowledge that, given conditions of underwater explosion as they were at Crossroads, the problem of radioactivity, in any immediate sense, is understandable and even manageable. There is less reason for dread if it is known, as it is now, that even the long-range effects may have expectable terminal points. The fragmentary answers gathered at Bikini might be stated thus:

First, Bikini still has within its life system some of the Baker Day radioactivity. The mud of Bikini at the target area is "mildly radioactive." The half-mile sludge bed contains fission products that are being fed constantly into the cycling currents and into all forms of life exposed to them. This is not to say that even the target area is "hot." It probably would be possible now for a man to walk on the bottom of Bikini lagoon without exposing himself to a radiation dosage that would approach the present concept of human tolerance. But because the residual activity is stable and long-lived, its traces will be found for many years.

Second, the radioactivity of Bikini, carried about the lagoon and absorbed into the tissues of living creatures, has been held there in greater amount than might have been expected. The absorption has slowed up the cleansing process. Furthermore, there has been a continual transfer of radioactive materials from the target area to a specific place, the eastern islands and reefs. The cleansing has been slowed, and activity has been concentrated in a way that seems to defy the cleaning action of water. Such concentrations may be eliminated only when the activity has decayed at its own normal rate.

This motor vehicle, its nose almost covered by trailing vegetation, stands on Bikini Island near the old highway sed by the Seabees and other personnel based ashore during the preparations for Crossroads.

Third, bits of radioactivity have been found in ll forms of life known to have been exposed to it. This does not mean that activity is found in all pecimens. But it has been demonstrated that activ-y can be transmitted in the food chains to crea-ures not exposed at the original source, that some orms absorb activity with astonishing rapidity, and hat some animal organs, such as the liver and pleen, seem to be storehouses especially important n the total process.

Because Crossroads was not conceived as the tarting point of long-term work in radiobiology, all he subsequent research has been after the fact, a rocess of picking up pieces and trying to fit to-ether a very complex puzzle. It has been an ex-eriment with few rules and no controls. This really s not significant now, for Bikini still is serving a seful purpose, although the biologists, looking ack on their four years of experience, see many ays in which they might have improved their performance and increased their knowledge if they had realized, in 1946, that Bikini would occupy their thoughts and claim their energies for so long a time. The Bikini research probably will continue for a short while. It is possible that scientific spot checks may be made there, occasionally, for years. For if the radioactivity is low, it also is of sufficient quantity to make the study of it both possible and necessary. So long as the activity is above normal there will be curiosity about its workings.

There are people who would like to live on Bikini. They are the Marshallese natives whose forebears inhabited the atoll for so many centuries and who were moved from their little homeland before Crossroads. They live now as wards of the U. S. Navy on Kili Island, in the Southern Marshalls, and they await the time the men from America say they may return.

But that time is not yet.

Tiquisate: A Call for a Science of Human Affairs

ELIZABETH E. HOYT

Author of The Income of Society, *published last year, and a teacher in the field of consumption economics, Dr. Hoyt is now abroad on a Fulbright grant doing research on technological change as it affects standards of living in certain British colonial areas. She is interested in the organization of a research group of employers in international investment, through which the collaboration of social scientists can be made more effective.*

TIQUISATE, a town owned by the United Fruit Company on the west coast of Guatemala, will be used in this paper as a symbol of the need for a broader and better-integrated social science. It illustrates both old and new problems, but particularly types of problems we are finding and likely to find in still greater degree in the development of large-scale investment in technologically less advanced countries. Point IV, or the extension of such investments, was characterized in President Truman's inaugural address as an "aim to help the free peoples of the world, through their own efforts, to produce more food, more clothing, more materials for housing, and more mechanical power to lighten their burdens." In June 1950, in another address, he spoke further of "the common desire of the peoples of the world to work together for human advancement. In a world dark with apprehension, Point IV offers new hope . . . constructive ways to build the kind of world where all nations can live in peaceful prosperity, dedicated to the purpose of creating better lives for their people."

The issues involved in attaining this creative and far-reaching ambition, however, are more difficult than official addresses and publications have so far indicated. Of profound importance are the psychosocial problems of extending our ways of production, and of life, among peoples who are of different cultural backgrounds from ours and in a different stage of political development. The potential economic effects of increasing production cannot be abstracted from the actual psychosocial effects; and it is possible, if we are not careful, that the disorganization accompanying the latter may be greater than the constructive services of the former. To meet these problems of international investment, we need to a degree never needed before a social science that takes account of them all. In fact, if civilization as we know it is not to have a new setback, this science we must have.

An analysis of the social situations where international or colonial investment has moved into a so-called backward area, and of the means for resolving the problems that arise, calls for a synthesis of knowledge, involving economic theory, anthropology, sociology, psychology, political science, and history, and the contribution of each of these disciplines must be weighed and evaluated in relation to the contribution of every other.

Social Research in Central America

Together with my students, and in cooperation with the Inter-American Institute of Agricultural Sciences in Turrialba, Costa Rica, I have been making studies of different types of large-scale investments and their social effects in "backward" countries, with special reference to Guatemala, over a period of four years. Over a much longer period a good deal of research has been done in Guatemala and in neighboring territories by anthropologists and other sociologists (Robert Redfield, Sol Tax, John Gillin, and others), the study of which has been of invaluable service to us.

At one extreme in our studies in Guatemala was an isolated village in the mountains, where a modern mill had been operating for several generations, but where comparatively few other changes had been made. Here no trains or buses made regular connections with the outside world. For the first years the mill was, as it were, encysted:

the people came to it in the morning and went out of it at night as if it were a foreign body which gave them their livelihood but which had little else to do with them. Later the old village life, the old patterns of living, began to be disrupted. At the time of our visit, however, the man most responsible for policies at the mill was himself a native of Guatemala and sensitive to the people's reactions; he was trying to encourage changes acceptable to them and to use methods in harmony with their established values. His efforts, the conservatism and isolation of the native group (which was small), and its slow increase in purchasing power, together brought about a situation which, at the time of our visit, at least, appeared to be a good example of a slow and substantial rise in the standard of living without an accompanying major social disorganization.

In a midway position was a group of establishments partly urban but largely rural. This comprised fifty plantations producing the country's basic commercial crop, coffee. The effects of technological change and employers' policies on the workers varied from something approaching those in the isolated mill village to the major disturbances at Tiquisate.

Tiquisate is an experiment in productive efficiency on a far more ambitious scale than any of the other places visited. The town and its farms, built by the United Fruit Company in the jungle, extend over a diameter of twenty-five to thirty miles, the headquarters of banana operations on Guatemala's west coast. United Fruit is responsible not only for the modern methods of banana production that Tiquisate illustrates, but also for the building and operation of the railroad, over which an endless series of banana trains passes on the way to the eastern port. The company is responsible also for the building and operation of the ships by which the bananas finally reach the United States.

But, if Tiquisate is an outstanding example of productive efficiency, it is also an outstanding example of social disorganization, even to the extent that the latter threatens the former. This is evidenced by a great deal of drunkenness and prostitution—which the people themselves deplore—by lax family relations, and by strong social antagonisms. Because Tiquisate is an extreme case, it is not, of course, typical of Guatemala, but cases of like social disorganization are easily found in other parts of the world. Over large areas of Africa, for instance, there are examples of similar and quite as serious problems, of which we do not hear because they do not react directly upon us.

The causes of the disorganization at Tiquisate fall into two classes: those rising directly out of the local situation, and those in which the local situation reflects attitudes in Guatemala and in Central America as a whole. With regard to the latter, it might be supposed that countries that have already made a substantial start toward the acceptance of applied science, as Central America has, would receive foreign investments with more favor than regions where technology is little known, whether of scattered population like central Africa or of dense population like parts of China and India. Theoretically, this may be true, but the facts are that the areas into which technology has penetrated are in most cases also regions of rapidly changing political consciousness, and the favor in which it is held, considerable though it may be, nevertheless may be less than the disfavor which such countries feel toward the penetration of outsiders.

The basic source of social disorganization at Tiquisate lies in the fact that the establishment of the town involved the disruption of an established cultural pattern without providing conditions favorable for the establishment of a new one. Although new values appeared, they did not take the place of the old; neither did they furnish a framework within which the social and psychic aspects of the people's old life could find their place and get the necessary response. The company provides the people with certain material advantages (a good hospital, toilets, garbage disposal, screens). In the beginning the people did not fully appreciate these, and in some cases actually resented or resisted them. They have been learning to value these health and sanitary facilities, but the process is a relatively slow one. At the same time, moreover, that the company gave material services, it failed to supply others that the people considered very important, such as privacy in their homes and a chance to grow plants and flowers. Also, old and familiar types of social relationships were broken down, and opportunities for new ones were either not given or were insufficient.

Related to the problem of cultural pattern but a different aspect of it is the fact that owing to a combination of circumstances and pressures the workers were paid very high wages in comparison with those paid for similar work elsewhere in Guatemala, and conditions were such that their standards of living* did not rise as fast as their

* See Davis, J. S. "Levels of Consumption and Standards of Living." *Am. Econ. Rev.*, 1 (March 1945). This is the *locus classicus* for definition of terms.

money incomes. As a result there was a great deal of hit-or-miss spending (through some of which, it is true, new standards might later be learned), and large amounts went for liquor and prostitution —a temporary escape from a distasteful social environment, but in many cases leading directly to even greater disorganization.

So much for the local problems of Tiquisate: the problems of a company town, of a boom town, and of a cultural conflict. But Tiquisate reflects, also, changes in political attitudes going on in Guatemala as a whole, which we have suggested by saying that the political pride of nations, their desire to be independent of aid that involves the interpenetration of others, may be stronger than their desire for increased economic production. Specifically affecting the feeling of workers in Tiquisate toward their employer is a widespread critical attitude toward business from outside Guatemala. The fact that the United Fruit Company is forced to pay wages higher than are paid for similar employment elsewhere in Guatemala reflects this critical attitude. Years ago, when the government was weaker and there was less widespread national self-consciousness, the company in various cases gained certain privileges, which some of the people now feel it never should have secured. It gained these, necessarily, by dealing with government officials, but it has not been uncommon in Central America for a new government to resent bitterly the acts, though legal, of the old.

To understand the force of this, one must keep in mind the immense importance of politics in Central America, and the difficulty, sometimes the impossibility, of knowing who the people's representatives really are. People in the United States have frequently given their praise to a Central American party on the strength of its proposed program, without waiting to see whether (and how) that program was to be carried out.

When a foreign company receives favorable concessions from a party whose policies in international investment are later repudiated, it is natural that resentments to these concessions should appear. Add to these resentments over relationships and contracts in the past the effect of a rising national consciousness disposed to be critical of foreigners, whoever they are, and you have a political situation with which it is very difficult to deal. It becomes even more difficult when Communist agitators take advantage of it and the social unrest—promising that with them for leaders all problems will be solved.

Here we have, in sum, a situation to which various shortsighted policies have contributed. But what is basically to blame is the inadequacy of social science, or at least the inexperience of social science, in dealing in a practical way with a complex problem that needs to be attacked as a whole. And yet we already have, in one form or another, single separate aspects of specialized knowledge that are applicable in such a situation.

The Contributions of Various Sciences

We have spoken of the unrest that comes from a disturbed cultural pattern, the framework in which life is carried on and in which each aspect of that life finds its place in relation to the rest. The importance of cultural patterns is the contribution of anthropology. Social evolution is bound to disturb cultural patterns: that is the price of an enlargement of understanding. Cultural patterns, however, need not be disturbed more deeply or more rapidly than the people are able to tolerate.

To illustrate: When people are moved, as is the case at Tiquisate, into a new environment that does not in itself offer opportunity for the expression of aesthetic tastes important in the old environment, an outlet for the satisfaction of those tastes can be deliberately supplied. An example at Tiquisate is the people's love for plants and flowers, which the crowding together of row houses in the new environment offered scant means to gratify. Yet such means might easily be provided. The employer did not think of it in laying out the town, simply because such tastes are perhaps not so important in the United States as they are in Guatemala.

Sociology is the science that emphasizes the importance of the social group as partly determining both the behavior and the adjustment of the individual. Some degree of group identification, whether overt or covert, is essential for the individual's sense of his own psychic security. Thus, any situation in which family life or any other old familiar groupings are broken up or threatened, as is the case at Tiquisate, calls for special attention to preserve the old or to create new groupings to take their place. Just exactly what new groupings would be most effective in a given situation must be determined in part by experiment. In some places competitive athletic groups have been a part of the answer. In any case, however, the new groupings should be planned to take account of the needs of women and children as well as those of men.

Psychology is involved in anything that has to do with the wants of the people; hence it is indirectly a part of anthropology and sociology. But it is also involved more directly in the attitudes of

the people toward the goods and services provided in Tiquisate, either as free services or through markets. For instance, are the people getting what they want in housing or only what the company thinks is good for them? Our study showed that they wanted more privacy than they got in the row houses. This could easily have been given them. Also, it showed that they did not fully appreciate, and in some cases did not appreciate at all, the sanitary facilities furnished by the company. There is no question about the need for these facilities, but many of the people do not know that there is a need; hence the values represented by the resulting better general health do not react in the people's consciousness. Educational psychology can find methods by which these improvements can be associated with something the people already value, so that they can be led into a realization of the importance of new ways. Behaviorism, association psychology, and Gestalt psychology can all make contributions to this.

One of the troubles at Tiquisate is that purchasing power has gone beyond standards of living. An increase in purchasing power, when a corresponding increase in means to use it is not also at hand, does a people slight service, and it may do them harm. When purchasing power rapidly increases, the market should offer a wide selection of goods, and new forms of recreation should be made available at reasonable prices. It is well known that when purchasing power is large and opportunities to spend relatively small, drink and prostitution are likely to become major outlets, and this is true not only at Tiquisate but elsewhere. The value of wages, like the value of everything else, is relative to the conditions in which they are applied.

In the process by which standards of living catch up to purchasing power, the psychology of want formation is again involved. Into this comes the creative function of marketing, the study of the acceptability of different types of new goods and services under different conditions. This is closely related to educational psychology. It is not so much that we say that the people of Tiquisate should be told they should not drink or take up with prostitutes, but only that they should be given a wider opportunity to make selections on their own account.

History and political science partake less of the nature of science than any of the disciplines mentioned hitherto, but it would be difficult to understand the broad conditions in Guatemala that affect the attitudes of the Tiquisate workers toward the United Fruit Company without a knowledge of political science and something of the history of Guatemala. Under ordinary circumstances, nations go through stages of gradually increasing national consciousness and, as we have said, there may be periods when the importance of their economic development seems to them secondary to the establishment of their political sovereignty and the expression of their national pride. When a nation is in such a sensitive period it is worse than a waste of words to argue with it that interpenetration by foreigners, even with the best intentions, will be to its economic benefit. In Guatemala at the present time the people need to assure themselves of their dignity as a nation and their ability to be independent of the United States and its institutions. They are open to influences friendly in the best sense, but they need to have the friendliness proved. The people of Guatemala respond to those among us who are sympathetic, but they know our mistakes much better than we know them. In particular, they feel that the intercourse of nations should not be so one-sided as ours with them has tended to be: that they have values to give us, if we could only see them.

The political factor is the one most difficult to deal with in the Tiquisate situation, since government, as a science, can as yet give us very little guidance in it. Yet the spirit of scientific approach is available. Nations in the stage of those in Central America may be compared with adolescents who resent—and rightly resent—being coerced, cajoled, or propagandized into a mold pleasing to others. Those who wish to help these nations must realize that nations, like human beings, have their growing pains, and that they need to find their maturity in their own way. Any attitude of superiority on our part, or of helping them merely to be like us, is fatal, and it ought to be.

When the influence of political attitudes in Guatemala is combined with the social disorganization already present in Tiquisate, it is not surprising that Communist agitators, with their ready promises, appear. Guatemala reminds us of Aristotle's discussion of the evolution of political systems. The mistakes or excesses of one system, if they are not remedied, pave the way for the introduction of another. The terms we use are more modern than those of Aristotle, but the fact remains that in trying to understand nations it is only in the light of yesterday's politics and what they encouraged or permitted that we grasp the significance of the politics of today.

Finally, we must take account of the importance of economics in this situation. Tiquisate and the United Fruit Company itself are experiments in

economics, examples of issues with which private enterprise has to deal. The problems of Tiquisate must be remedied within the framework of the economic resources available. For no enterprise are these resources unlimited. Economics is the science of choice among scarce means, the science of knowing the significance of different ways of attaining a desired end, and the relative costs of these ways in relation to their contributions to that end. Whether the desired end is profits, as is the assumption with regard to private-enterprise institutions, or whether it is something else, such as power or prestige or equality of opportunity for human beings, there is always an economic process to attain it, and the value of every possible approach must be weighed against the value of every other.

A special aspect of economics remains to be mentioned, basic if productive organization is to continue and increase. So far, in discussing Tiquisate, we have taken its productive organization for granted, and addressed ourselves only to problems of social unrest and dissatisfaction. But productive organization is also a part of the broad problem of social science, and it is possible by overemphasizing other social values to destroy this one or, in a new situation, to prevent it from arising. Guatemala has other enterprises where some of the troubles of Tiquisate have been avoided. Some of these are collective enterprises, and no intelligent person could fail to recognize the broad idealistic principles behind them; but efficient productive institutions these particular enterprises could not be said to be.

It is true, as we have emphasized, that people at one stage of their development may prefer other things to productive efficiency, but even though the latter may be a secondary value it is a value nonetheless. Just as we tend to underestimate or overlook some of the values of other peoples, so critics of our productive system tend to underestimate the imagination and courage, the ability to organize, to integrate, and to keep track of detail, that are required to build and operate a productive enterprise. They tend to assume that any well-intentioned group can do it, without the rewards of profits or of power, and under conditions of extreme restriction and control. That is the theory of the Communist agitators in Tiquisate, and it is the theory of Communism everywhere. Along with the other problems with which our master social science must deal are the conditions under which men are willing and able to create great enterprises and to manage them well. The final issue is to secure such productive efficiency as Tiquisate illustrates and at the same time to take full account of the other diverse and manifold needs of men for adjustment, security, and growth; or to put it the other way around, to take full account of the diverse and manifold needs of men, including those needs that productive efficiency alone can meet.

An Organic Social Science Needed

We have run briefly through some of the more important ways in which different social sciences affect the Tiquisate situation. Yet for attack on the problems at Tiquisate it is not enough to bring together a set of different social sciences, each science to be allotted a part. A half dozen social scientists, each a specialist in a single discipline could, it is true, offer advice at Tiquisate and in similar situations, but each by himself would tend to overestimate the importance of his own science, and perhaps even seek to apply it in ways that would interfere with more pressing needs outside his own province. The fact is that every science reacts on every other, and policy with regard to one cannot intelligently be set up unless the others also are considered. It is not enough to remedy mistakes or to set up new enterprises with a dose of anthropology here, of sociology there, and of economics and psychology somewhere else. The larger whole must always be the final consideration. It is obvious that one great source of trouble in the past is our overemphasis on the services that our material values would render to Guatemalans, and to ourselves. It is very likely that other, no less serious troubles would arise from underestimating the difficulties with which productive efficiency is secured, as the critics of our system do. Any single social value can be secured at too high a price. The situation must be seen as a whole, and the science that deals with it must be organic.†

And, after all, that is perhaps not too difficult. What each discipline or portion of a discipline contributes to the sum total of human wisdom is a general truth, or sometimes chiefly a point of view toward truth. A large body of detail may be necessary to establish that truth in the first place, and after it is established thousands of minute studies related to particular applications may be made.

† In the December 1949 issue of The Scientific Monthly, in "The Sciences of Human Learning, Society, Culture, and Personality" (pp. 377–80), G. P. Murdock raises the question as to what should be the name of an integrated science of human affairs. I propose the name of "anthroposophics" or, even better, "symbiotics." In its original Greek use *symbiosis* was applied to the living together of human beings; a *symbiotes* was one who lived with another.

Nevertheless it is not necessary to go through all the details and be familiar with all the studies to use the basic scientific principle when once it has been made clear. One reason why the possibility of an organic science has seemed remote is that each main branch of it, in its years of immaturity, sets in motion masses of smoke around its central point of light, so that too frequently outsiders (and sometimes insiders, too) have only glimpses of the light, or perhaps see smoke alone. The need is to dissipate this smoke from the human landscape so that each light will illumine a single part and each will contribute to a better illumination of all.

It was the pressures arising out of a practical demand, a demand for defense, for weapons of war, that more than anything else advanced the synthesis of the physical sciences. Because we believed that it was urgent to create new defenses through physical science, we found that we could do so. But the need for understanding how men of different backgrounds can live together to mutual advantage, and at the same time move forward, is a greater need, and it requires only slightly more imagination. Perhaps Tiquisate does not present all the issues that an organic social science would have to meet, but it is hard to see how any single place could present a more urgent need; especially is this true since in Tiquisate one of the two major political systems of the world is challenging, and has clear reasons for challenging, the other.

At all events, if we can deal in a masterly way with Tiquisate, the foundations of such a science are laid. More knowledge is needed, but we already possess more than we have put to effective use. The call now is for humility with regard to the importance of any single aspect of social knowledge, for vision and imagination in the application of social knowledge as a whole.

MOUNTAIN HIKE

EASY to see as the blood keeps pace
The sides of earth careen, expand:
I harry a road of webs and space.
Wind is a river that lends a hand.

The foot slaps hard; the path is a stroke,
And I have warmth, body and bone,
Like the cool birch, like the gnarled oak,
And others that course the light alone.

There are worlds in rough clods underfoot.
I see the sails of wet webs caught.
The hawk swings slow and resolute,
And valley lands are stretched and taut.

The world has dawn piled on its back.
All pulses strengthen as they beat.
My brothers, the winds, unfold on the track,
And the mountain's side is brushed on the feet.

DANIEL SMYTHE

Some Recent Advances in Ceramics*

WILLIAM RODERICK EUBANK

Since first studying ceramics in the graduate school of the Pennsylvania State College School of Mineral Industries in 1941, Dr. Eubank (Ph.D., physical chemistry, Johns Hopkins, 1947) has been engaged in ceramic research on refractories, enamels, whitewares, insulation materials, and ferroelectric crystals. He has been Fellow of Industrial Research at Mellon Institute and Research Associate at the National Bureau of Standards and has been associated with the U. S. Naval Ordnance Test Station, Inyokern, China Lake, California, since 1948 as Ceramic Consultant.

CERAMICS, perhaps the oldest technology, originated in prehistoric times when man first fashioned and then fired, in all probability by accident, useful and artistic articles from clay. Indeed, evolution of ceramics has been the archaeologist's chief gauge of advance in the world's civilizations. Today ceramics has undergone extensive diversification and embraces such well-defined and distinct technologies as abrasives, refractories, enamels, glass, cements, clay products, and whiteware, as well as a number of special, somewhat isolated fields, including ferroelectric ceramics, phosphors, ceramic dielectrics, semiconductors, and ceramic fibers. The boundaries of these fields are flexible and touch the domains of other technological endeavor. Ceramic products, however, have in common the fact that they are all derived from raw materials of mineral origin, which usually require heat treatment ("firing" or "maturing") at some one or more stages of their processing. The study of the chemistry and physics of these materials derived from the earth has yielded data the application of which has permitted development of new products, processes, and techniques. Vigorous investigation of a fundamental nature must be pursued in the future for the quantitative elucidation and understanding of the behavior of matter and energy involved in the fields of ceramics. In the words of Herbert Insley,[1] chief of the Mineral Products Division, National Bureau of Standards, "The growing use of ceramics for special applications in electronics, transportation, and ordnance under extreme conditions of space limitations, temperature, electrical load or mechanical stress has compelled a searching examination of the constitution and fine structure by every applicable physico-chemical means."

Advantages for the use of ceramics are the abundance, wide distribution, and general low cost of raw materials, ease of fabrication, and particular properties, such as refractoriness, hardness, and dielectric behavior not found in other materials. Some disadvantages of ceramics are their low strength in tension, or "brittleness," lack of uniformity in some cases, and generally poor resistance to thermal shock. Certain of the refractory oxides, however, such as Al_2O_3, have compressive strengths equal to or greater than those for the best steels—i.e., 300,000–400,000 psi at ordinary temperatures. At elevated temperatures the ratio of the strength of the ceramic to that of the metal rapidly increases until the metal fails completely. Members of the metallic carbide, nitride, and boride classes of ceramic materials—for example, TiC—are reported capable of being rapidly cooled from temperatures in excess of 2,000° C without cracking. The thermal efficiency of heat engines has been vastly improved in many cases by the use of refractories, protective coatings, or ceramic insulation.

The design engineer of the future will be forced to give full consideration to ceramics. The advancing frontiers of transportation, industry, and warfare demand increasing efficiency in the production and control of concentrated energy. This involves higher and higher temperatures and materials that will withstand such high temperatures. In most

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cases these high temperatures are encountered under oxidizing or corrosive conditions. Heat engines, in general, are now being operated in the upper temperature range for metals, that is, at temperatures just short of those at which the available metals fail. Significant further improvement will probably be made by using ceramics. This must be done, of course, by intelligent use with metals—making full use of the advantageous properties of each material. For example, a refractory insulating ceramic when suitably mounted in a metal tube will allow sustained exposure to internal temperatures several hundred degrees C above the melting point of the metal. It is in operations at high temperatures that the greatest challenge is offered the engineer. Slowly but certainly the use of ceramics is increasing, in particular by efforts of the National Advisory Committee for Aeronautics, the Air Materiel Command, and the Office of Naval Research, which are sponsoring several ceramic research projects. In most cases complete information on the properties of ceramic materials at high temperatures is lacking, and increased efforts by the universities, commercial laboratories, and government agencies must be made to fill this gap.

The westward population shift in the United States in the past few decades has resulted in a heavy demand for ceramics in the Western states. Not only must production of ceramic construction materials be greatly expanded to meet ever-increasing housing and transportation needs, but also important industrial ceramics, such as refractories, glass, and enamels, are required to keep pace with other technological growth. Abrasives, electrical and thermal insulation, and cements are also important adjuncts to other industrial development.

Ceramic Raw Materials

Raw materials for ceramics in general are widespread and abundant in the United States.[2] In the West, for example, vast deposits of magnesite occur in the state of Washington, Idaho possesses countless millions of tons of dolomite and limestone, Wyoming has large beds of phosphate rock, and Montana's natural resources include fire clay and ganister. California has large reserves of talc, Utah contains much gypsum and alabaster, and Colorado contains fire clays and feldspar. Clay of sufficient quality for brick and tile occurs in all the states. Kaolins, fire clays, or other refractory raw materials are found[3] in substantial deposits in nearly three quarters of the forty-eight states. Exploration for new deposits, however, especially in the West, appears necessary because of the economic advisability of locating deposits near centers of distribution and consumption. Close cooperation between geologist and ceramic engineer is indicated. In many cases a deposit, located usually by a geologist, can be properly evaluated only after careful tests by a ceramic engineer. Composition, impurities, removal of impurities, and final winning of the raw material are important. Many raw materials, such as the feldspars, are now recovered by flotation methods. Froth flotation removes a high portion of objectionable iron-containing minerals and allows lower-grade deposits to be worked profitably, yielding a high-grade product.

New methods of analysis, such as flame photometry,[4] by which more than 40 elements can be quickly and accurately determined, have recently been developed. New raw materials—fractionated kaolins, sierralite, new talc material, and garspar, a by-product of the glass industry—have been marketed.

New Ceramic Products

A field that has shown considerable recent development is that of synthetic crystals.[5, 6, 7] Synthetic sapphire has been produced for several years both in this country and in Europe. Lately many other minerals have been synthesized, including mica, quartz, rutile, magnetite, scheelite, barium titanate, tourmaline, mullite, asbestos, and others. Certain of these were in critical demand during the last war; others have important new uses as a result of properties not found in the naturally occurring minerals.

Reactions in the solid state, i.e., in the absence of a liquid phase, have been responsible for the production of so-called superrefractories. R. F. Geller and co-workers[8] at the Bureau of Standards have investigated several of the refractory oxide porcelains. Gas turbines with refractory buckets made from this type of ceramic have been success-

SOURCES OF REFRACTORY MATERIALS
in the United States

fully operated by the NACA many hours at high temperatures.[9]

The metallic carbides, nitrides, borides, phosphides, sulfides, and silicides are materials about which little refractory data are available, but which offer great potentialities for high-temperature applications.[9, 13] A solid solution of HfC and TaC is said to be the most refractory material known, melting at temperatures above 7,100° F. Many of these metalloids are highly resistant to thermal shock and the erosive effects of hot gases.

A new class of refractory materials, composed of mixtures of ceramics and metals and called "cermets,"[10] has recently been developed. Some of these bodies have very high loading strengths at high temperatures and good resistance to thermal shock.

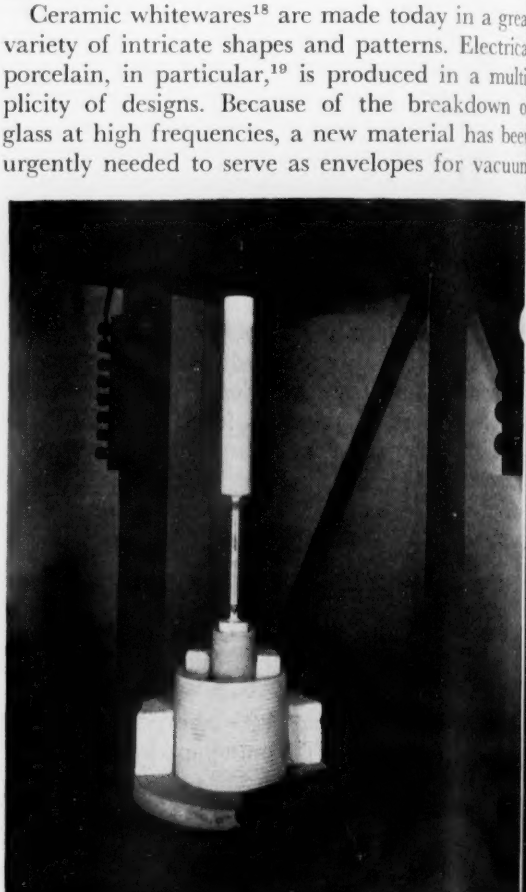
The use of ceramic coatings is of interest because by this means a way of extending the operating temperature range of metals is possible; in other words, metals may be used at temperatures at which they would otherwise fail. Coatings have been developed that are corrosion- and oxidation-resistant, thermal- and electrical-insulating or -conducting, and radiation-suppressive. In some cases these coatings have the additional advantage that they may be applied to existing metallic designs. Coatings for steels, "stainless" steels, aluminum, tungsten, molybdenum, and other metals have been devised. Studies conducted at the National Bureau of Standards[11] have indicated the striking longevity of coated metals in corrosive atmospheres at high temperatures as compared to the short lives of uncoated specimens in the same tests. Other enamels and glazes have been developed for zircon porcelain[12] and other low-expansion ceramic bodies. A novel method of applying coatings consisting of deposition from the vapor phase[13] has been successfully employed at the Battelle Memorial Institute.

Research in glass ceramics has yielded photosensitive, conductive, and selective-absorptive glasses. New glass-to-metal seals, as well as ceramic-to-metal seals, have been produced. Silicate structures, transitions, hygroscopicity, and surface tension of glass systems have been studied, although much yet remains to be learned in order that we may have a clearer picture of the "glassy state."[14, 15]

Investigations of cements have produced better chemical-resistant and refractory materials. Researches on portland cement[16] have led to substantial improvements and a wider specialization in its uses. Painstaking study of the phase-equilibrium relations in many of the chemical systems involved has been responsible, in large measure, for the establishment of five standard types of portland cement, each type being uniquely suitable for a specific application.

In the field of abrasives, new carbides, borides, and nitrides have been produced. Fundamental studies are now being conducted on the abrasion hardness of single crystals.[17] Efforts are being made to explain in a quantitative way how a crystal can be ground or abraded away with smaller particles of the same substance. Studies of the vector abrasion hardness of diamond, periclase (MgO), spinel ($MgO \cdot Al_2O_3$), and silicon carbide (SiC) have been made. High-alumina spinels offer considerable promise for use as cheaper bearing material because they are only slightly softer than synthetic sapphire and can easily be processed with the latter abrasive.

Ceramic whitewares[18] are made today in a great variety of intricate shapes and patterns. Electrical porcelain, in particular,[19] is produced in a multiplicity of designs. Because of the breakdown of glass at high frequencies, a new material has been urgently needed to serve as envelopes for vacuum



The amount of elongation and the tensile strengths of special ceramic bodies for high-temperature applications are determined in tests at the National Bureau of Standards. A specimen prepared from one of the special high-temperature ceramic bodies is shown in position for creep tests with the ceramic adapters through which the stress is applied. Construction of the electrically heated furnace is revealed by cut-away portion at the bottom. (Photo by courtesy of National Bureau of Standards.)

tubes. Recently porcelain vacuum tubes[20] have been successfully produced.

In the structural clay products field one of the most interesting developments is the "all-ceramic home."[21, 22] Several models of ceramic houses have been built in different localities throughout the country and are undergoing extensive tests. These houses are made with ceramic foundations, walls, floor, roof, mortar and joints, windows, and heating systems. In certain houses, pipes are cast into the floors for heating; in others, hollow walls serve for heat storage or air circulation. Advantages claimed for these new homes are their excellent livability, crack-proofness, simple, inexpensive heating and cooling systems, high fire safety (fire insurance rates are said to be about one tenth those for a frame house), and low depreciation.

Special ceramics, such as the phosphors, glass and mineral fibers, dielectrics, and piezoelectric ceramics are finding wide modern usage. Signs, screens, and television tubes are made to "glow"—fluoresce or phosphoresce—when irradiated with various wavelengths of energy. Laminated glass has exceptionally high strength and resilience—fiberglass rods are successfully displacing bamboo in the fishing tackle market. Miniature devices, such as hearing aids, make extensive application of high-dielectric constant ceramics (barium titanates).[23, 24] The average television set contains about one pound of this new dielectric. Phonograph pick-ups, medical devices, such as the cathemeter and ballistocardiograph, and other devices employ piezoelectric ceramics.

Ceramics are of interest in atomic energy applications[25] as refractories and moderators in thermal piles, shields from harmful radiations, and detectors of radiation—for example, scintillation counters employing synthetic crystals of $CaWO_3$.

New Methods in Ceramics

Production and measurement of high temperatures have been the subjects of considerable recent research. Temperatures in the range 2,000°–4,000° C have been produced by arc and induction furnaces. These have the disadvantages of small heating area and lack of control in the first case and necessity for employing sealed furnaces and vacuum or inert atmospheres in the second. Recently, however, oxide resistor-type furnaces[26, 27] have been developed, by means of which moderately high (2,500° C) temperatures can be reached under oxidizing conditions. Resistor rods and tubes of zirconia or thoria have been employed. Another method of attaining high temperature, that of burning metallic aluminum in oxygen, has lately

Furnace for developing porcelains to be used as turbine blades and other stress-carrying parts of turbo-jet aviation motors heats ceramic specimens at temperatures up to 1,900° C in an oxidizing atmosphere. Natural gas is mixed with preheated air before combustion. The bars being set in the muffle will be heated at the appropriate temperature for maturity and then used to determine resistance to thermal shock and forces required to bend or break the specimen. (Photo by courtesy of National Bureau of Standards.)

been demonstrated.[28] Study is being conducted also on the focusing of solar energy by means of large parabolic mirrors, and temperatures as high as 3,700° C[28] have been reported. Advantages claimed for this method include cleanliness, absence of electrical interference, quick heat, and an oxidizing atmosphere. Disadvantages are a small heating area and dependence on the weather.

New methods for measuring high temperatures have also been given consideration. Thermocouples[13]—for example Mo-W—for use at temperatures of 2,000° C and above have been tried. The chief problem encountered is finding a satisfactory protecting tube for the hot junction. A new method for high-temperature measurement, termed "noise pyrometry,"[28] is under investigation at the University of Chicago. Employing the principle that the root mean square of the radio frequency generated by thermal agitation in resistors varies with the temperature, the method compares "noise" from a known cold source with that from the unknown hot source through a null circuit, with an accuracy and precision of about 0.1 per cent.

Ultrasonics[29] appears to have several possible applications in ceramic technology. When microwaves pass through materials, some of the effects produced are absorption of energy, cavitation of liquids, or acceleration of particles. Thus heating, emulsifying, or grinding is possible, depending on the particular apparatus and medium employed. An important use of ultrasonics is in the nonde-

structive testing of large objects and structures where cracks or flaws give abnormal propagation of ultrasonic waves, with modern electronic equipment without damage to the test specimens. Another possible use of ultrasonics in ceramics may be in the vibration of molds during casting, reducing thixotropic behavior and requiring less deflocculant and liquid in the slip, resulting in less drying and shrinkage of the cast ceramic body.

Another relatively new technique that has possible application to ceramics is that of radioactive tracers.[30, 31] Such problems as the study of contamination of glass during melting, corrosive action on refractories, the rates of solid solution reaction between two mineral phases, or determination of diffusion coefficients of elements or compounds moving into crystals or glasses offer good promise of ready solution by this method.

The electron microscope has been used on numerous occasions to give a better picture of the fine structure resulting in various ceramic processes. An example of this is the calcination of magnesium oxides.[32] Electron micrographs of magnesium carbonate or basic carbonate calcined at low temperatures (300°–400° C) reveal very porous and highly active pseudomorphs after the original material. At higher temperatures (above 900° C) almost perfect cubes may be observed, which then sinter together and grow in size as the temperature is raised.

The technique of X-ray powder diffraction at high temperature has been studied at the Bureau of Standards[33] and is a valuable tool for investigating transitions and modifications in crystal structure during the firing of ceramics. For example, the low-high quartz inversion which is generally referred to as "instantaneous or rapidly reversible" has been observed by this method to actually begin 100° C or more below the accepted inversion temperature and to continue far above it.

A new means of depicting in a systematic manner the simultaneous phase-equilibrium relations in a quinary or five-component system by graphic or analytic procedures has recently been published.[34] By this method a number of the complex phase relations found in many ceramic materials may now be studied.

The understanding of the mechanical properties of ceramic materials is the object of some of the work under Dr. Eyring at the University of Utah.[17] The concepts of Eyring's absolute reaction rate theory are being applied to ceramic systems. Data presently to be made available on the creep, flow, and fracture of glass have been subjected to theoretical evaluation.

Possible Substitution of Ceramics for Strategic Materials

It is said that we are rapidly becoming a "have-not" nation in certain cases. Certainly the staggering demands of two global conflicts have made inroads into our available supplies of some materials. This can hardly be said, however, of our vast ceramic raw-material resources. It becomes obvious, therefore, that in the foreseeable future, substitution of ceramics for certain metals, say, will have to be made.[35] Such strategic materials as chrome, used in great tonnages as chrome-magnesite refractories, or manganese, employed as a decolorizer for glass, may be substituted for by other recently developed ceramic products. An all-ceramic house saves many pounds of metal and other materials and still can be made durable and comfortable from abundant and expendable raw materials. It is suggested that, in any move to conserve or allocate our strategic materials for a possible future emergency, knowledge of our ceramic resources, and what they can accomplish in replacing needed metals and fulfilling the requirements for construction and manufacturing, might also be worthy of stockpiling.

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RIVER BOUNTY

OLD MUDDY give her to me," Eben said,
Whenever folk set strange foot on his farm,
But they just thought him teched. I did myself
Till Pratt, an old surveyor, set me right.
"You don't believe him, eh?" Pratt said. I smiled
A slow and knowing smile to turn his joke.
And then he told me truth of stranger offering
Than any book—how back in sixty-five,
A wild Missouri belched a sudden island,
Two acres big, nigh onto Eben's shore.
It farmed right well and when, in time, he asked it,
The state gave deed. The fitful old Missouri,
Never faithful to any bank, turned northward,
And through slow years of soft or thunderous water—
Always receding, eating the new channel—
Good land crept out from under to be a farm.
Call it accretion, as the records do;
Call it freak of nature, but never call
Old Eben Scott a fool when he waves an arm
And says, "Old Muddy give me this here farm."

ISABELLE BRYANS LONGFELLOW

SCIENCE ON THE MARCH

RECENT PROGRESS IN TROPICAL MEDICINE

FOR perhaps the first time in history, plans are being made to rid an entire nation of a major disease by therapeutic methods. Preventive medicine has been employed on a nation-wide basis until now we accept it as commonplace, but the use of therapeutic measures for eradicating an infectious disease on a national scale is a new approach. Such a program is being organized in Haiti by the Pan American Sanitary Bureau for the eradication of yaws by the use of penicillin.

Yaws is caused by a Treponema that so far bacteriologists and serologists have been unable to distinguish from the one causing syphilis. Considerable discussion and argument have resulted as to whether the two diseases are not one and the same, but producing different outward signs due to environment. Specific culture methods will have to be developed to distinguish fact from fallacy.

Usually yaws is contracted by infants, and, undoubtedly, small biting insects are chiefly responsible for transferring the disease to uninfected individuals. It manifests itself first as a sore or pustule, commonly on some exposed part of the body. The secondary stage of the disease includes a generalized skin involvement of scattered ulcers and nodules. In the advanced stage, bone changes and deep discharging lesions occur in various parts of the body.

An ideal drug for mass treatment of any disease must have a wide margin of safety, low cost, and must be easily administered over a short period. Penicillin comes close to being the ideal drug for mass treatment of yaws. The activity of penicillin against this rather loathsome and sometimes incapacitating disease was first noted by Whitehill and Austrian[1] of this country and in Brazil by Da Cunha and his colleagues.[2] Dwinelle and his associates[3] and many other investigators confirmed the earlier work. It remained for Rein, Kitchen, and Petrus[4] to establish the fact that mass treatment of rural as well as urban populations was feasible and effective. The yaws prophylaxis campaign that is getting under way in Haiti is based largely on this well-controlled and carefully documented study.

The program will meet many hardships, but there are many advantages that will more than make up for the difficulties encountered. Although Haiti was one of the first regions colonized in the Western Hemisphere, as a whole the country is still quite primitive; there are few roads, and the population of more than 3 million is in excess of the number that can be adequately supported by the limited amount of fertile land in the country. This results in low economic standards and widespread poverty. The rural Haitian works hard on his small plot of poor ground but is unable to produce even the minimum required for an adequate diet and limited amounts of clothing and shelter. He is unusually grateful for medical treatment. When the doctors start their campaign they will find that they are well received and that the population will promptly respond when called on to receive their treatments. The appreciation that the Haitians show for medical assistance is seldom encountered in other countries. It will be interesting to follow this new approach to public health measures and observe its success. The degree of this success will undoubtedly depend upon the energy and dependability of the personnel conducting the campaign.

African sleeping sickness is caused by *Trypanosoma gambiense* and *T. rhodesiense,* protozoan parasites that swim freely in the blood stream of the human host after being introduced by the bite of the tsetse fly. These trypanosomes later enter the cerebrospinal fluid and invade the central nervous system, thus causing the neurological syndrome called sleeping sickness. As yet, no completely satisfactory measures have been developed for treatment of clinical cases, so it is logical that a great deal of attention has been paid to methods of prevention. One of the promising preventive measures is the en masse administration of prophylactic drugs. In several parts of Africa mass drug prophylaxis campaigns have been carried out, usually with injections of pentamidine or propamidine. Harding and Hutchinson[5] have this year published the final report on their part of the study in Sierra Leone. They found that the infection rate was reduced by over 75 per cent among the 8,000 persons treated with such prophylactic injections. In another study in French West Africa,[6] pentamidine injections were successful in completely protecting 1,002 persons for six months, whereas there were

19 cases of sleeping sickness among 902 controls.

The fight against sleeping sickness is also being carried on in fields other than drug prophylaxis. Control and eradication of the vector, the tsetse fly, has received a great deal of attention and consumed the energy of a large number of workers. Morris[7] reports the results of a successful campaign against the tsetse fly in the northern territories of the Gold Coast. He emphasizes the ease of maintaining tsetse fly control, and from his experience it appears that in areas with even moderate to low population density these measures can successfully control breeding of the vectors. Another important control program has been carried out in recent years at Anchao, Nigeria.[8] Here, by discriminative clearing of forest, by destruction of certain wild game acting as intermediate hosts, and by the use of DDT spray, a tsetse fly-free area of some 700 square miles has been created and has been maintained by people taught how to farm the land correctly. Likewise in French West Africa, in Rhodesia, in the Belgian Congo, and in other areas where the disease is endemic, this type of tsetse fly control, when thorough, has been highly successful.*

Schistosomiasis was until recently thought to be endemic in only a small area of South America (the Guiana region), but the work of Brazilian and other investigators has demonstrated the fact that it is a serious disease extending over a large part of northern and eastern South America. In Puerto Rico, it has long been a public health problem, and the immigration of Puerto Ricans to New York and other locations in the United States has brought the problem closer home. As a world problem, schistosomiasis is even more important; Shousha[11] points out that in Egypt alone 100 million people suffer from these parasites.

Schistosomiasis is unusual in that it is caused by a metazoan parasite that belongs to the fluke or flatworm family, which lives and breeds in the blood vessels of man. These flukes prefer the abdominal blood vessels for their abode, and the majority of the symptoms are produced by the eggs burrowing their way out through the tissues into the intestine or bladder in order to reach the outside and again start their life cycle. After these eggs hatch into free-swimming larvae, which attack anyone wading in infected water, they burrow their way through the skin of the victim and into the circulation, where they in turn mature and start breeding. There are three forms of schistosomiasis. One is predominant in the Orient. The second is a serious disease in Egypt and North Africa. The third, caused by *Schistosoma mansoni,* is widespread throughout the rest of Africa and South America.†

Although advances have been made in the treatment of this disease, no completely satisfactory remedy has as yet appeared. Fouadin and anthiomaline are the most effective drugs, but the cure rate is only about 70 per cent with either. This cure rate is determined on the basis of absence of viable ova from rectal biopsy specimens and from stools.

Interest in *tropical ulcer* has been stimulated by recent investigations in various countries. The cause of tropical ulcer has long been obscure, but the usually accepted theory is that it is caused by infection with Vincent's fusospirochetes in a debilitated, malnourished individual with vitamin B_1 deficiency. Results of Golden's[12] study in Guatemala cast serious doubt on this and other existing theories that would explain the origin of these indolent and incapacitating lesions. Possibly, rather than a vitamin B_1 deficiency, a predisposing factor is a lack of vitamin C. More than a hundred cases of tropical ulcer seen recently in British Somaliland[13] had diminished plasma levels of vitamin C, whereas 149 control patients without tropical ulcer had normal plasma vitamin C levels. Tropical ulcer is common in most countries that have a hot, humid climate. The incidence appears to be highest in the Amazon Valley. No set treatment has been established, and these ulcers, which generally appear on the lower leg or feet, often remain for years without healing. In the British Somaliland study just mentioned, the use of oral vitamin C was not helpful in speeding the healing process. Berry[14] in a recent article points out that probably more money is spent per patient on the treatment of tropical ulcer than on any other single tropical disease. Even when treated with success a scar remains which is always likely to break down, causing the ulcer to recur. Berry's study in Africa failed to establish a definite dietary background of the disease.

Yellow fever was referred to in a comprehensive review of tropical medicine,[15] and its importance in the northern part of South America was pointed out. About the time this review was written (end

*For anyone interested in a comprehensive, detailed account of the sleeping sickness problem in Africa, the complete picture is presented in a monograph published for the Colonial Office by H. M. Stationery Office, London, 1948.[9]

† A recent monograph from the Oswaldo Cruz Institute of Rio de Janerio on *S. mansoni* is unusually complete. The authors, Pinto and De Almeida,[10] deserve high praise for their exhaustive and detailed study of the serious and widespread disease caused by this organism.

of 1948), yellow fever occurred in Panama for the first time since 1905. There were 5 fatal cases near Pacora not far from the Canal Zone. A country-wide program of vaccination was immediately instituted and yellow fever fortunately did not become a major hazard there. Yellow fever has also appeared again during the past twelve months in South America, this time in the eastern lowlands of Bolivia, and reached epidemic proportions. Prompt action of the Rockefeller Foundation under the direction of George Bevier, of Cochabamba, chief of its Bolivian Branch, and the National Health Service authorities brought the outbreak under prompt control.

For those who are interested in the rare diseases that are seldom mentioned and of little economic importance, a description of several of these exotic diseases appears in the *East African Medical Journal* for December 1948. M. Gelfand, in his article entitled "A Few of the Rarer Diseases Seen in Africa," describes several of these little-known entities.[16]

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THE GEOGRAPHY OF PATHOLOGY

IN THE earliest days of medicine physicians knew little more about the causes of diseases than the places where they occurred. Environmental factors had, during the first centuries of medical knowledge, an importance they lost when Pasteurian discoveries focused attention on the study of pathogenic organisms. With further progress a renewed interest in environment developed, for it became clear that the organisms themselves were closely related to the milieu. Parasitology, epidemiology, and medical entomology take into consideration some aspects of the relationships between disease and environment. Medical geography professes to make the study of these relationships its principal objective.

The first aim of the medical geographer is to map the distribution of disease throughout the world. It is not possible to study the influence of the environment on disease if we do not know *who* has *what* and *where.* Once person, disease, and place are known, we may be able to understand *why* someone is afflicted and someone else is not. Geographical factors may emerge as paramount in the creation of the pattern of distribution. The measurement of the importance of these factors is the second aim of medical geography. It is thus a study of correlations.

Before we study the distribution of disease and its correlation with environment, we should define disease. It is the name we apply to evidence of the impairment of living tissues (pathology). For the purpose of medical geography it is convenient to divide pathology into two classes: (1) Pathology occurring as the result of the aggression of either animal or vegetable organisms. This comprises the group of communicable diseases. (2) Pathology occurring without aggression of either animal or vegetable organisms. This comprises all noncommunicable diseases. It can be further divided into two subclasses: pathology due to tissue changes that are essentially reversible by spontaneous physiological adjustments, and pathology due to changes essentially nonreversible. Traumatology, the study of injuries caused by violence, is not included, although it has important geographical aspects.

Distribution of disease. The first pathological class is definitely related to the environment. Un-

fortunately, for the world as a whole most medical phenomena occur in places where they are not observed, or if observed are not reported, or if reported are not properly filed and classified. Only a very small percentage of what happens in this field is accurately listed. All our knowledge of epidemiology is based on that small number of facts. But, however scanty the information and fractional the reporting, if we plot on a map of the world all available data on communicable disease, we find that a pattern definitely emerges. Certain diseases exist all over the inhabited world; others are sharply localized. Tuberculosis and syphilis seem to exist everywhere; yellow fever is now confined to a fairly well-defined region in South and Central America and Africa, and is not found elsewhere. But different forms of the ubiquitous tuberculosis and syphilis predominate in different parts of the world. The geographical distribution of variations in the same disease, and the various aspects of pathological changes due to similar organisms call for study. Why is it that tuberculosis is more deadly to Africans than to Europeans? That syphilis causes more cutaneous lesions in Mediterranean races or in people inhabiting the tropics, and more nervous-system pathology in people living in temperate climates? Filariasis, a disease caused by the introduction into human blood and tissues of certain worms, shows a definite distribution pattern explainable by the environmental requirements of the various types of worms and vectors responsible. The geographical distribution of dracontiasis, for instance, is coincident with the distribution of step wells—in India and Africa. The bearer of an adult worm steps barefooted into a well; larvae are expelled into the water and are eaten by a fresh-water copepod, which in turn is injected into the human body when the well water is drunk; the gastric juice destroys the copepod, liberating the larvae, which migrate to subcutaneous tissues and develop into new adults.

Turning to noncommunicable diseases, we consider first those pathological changes that can revert to normal spontaneously. Such changes are essentially of a transitory character, being largely a result of the impact of climate, and really belonging to the field of physiological climatology. They tend to disappear after physiological adjustment. However, repeated impacts of geographical factors such as climate, soil, and food on the human body can leave lasting effects and can help create a local human type. Such is high-altitude man of the Andes, whose blood may contain as many as 8 million red cells to the cubic millimeter, whereas sea-level man averages about 5 million.

The existence of certain types of local man deviating from the norm raises several questions. The first is one of definition. Where do we draw the line between an unusual physiological condition and pathology? Should we call the high-altitude man a "sick" person if he remains in his own environment doing the things he is trained to do, or only if he moves out of his environment? Similarly, a white man newly arrived in a tropical area will undergo a number of physiological adjustments, which it may fairly be stated put him in the category of the sick—because his physiological functions are disturbed; however, there comes a time when he is restored to health by adjustment to the new environment. At what time should he be considered "normal" again?

The second question is at present a speculative one. Considering again the type of man developed by high-altitude living and his children born with similar characteristics, what are the respective roles of genetics and ecology in producing local types? We shall not discuss the point, since all that we are interested in at the moment is a census of the various types of men, with their peculiarities, in the various geographical environments. We want to know the distribution of low-blood-pressure man, of low-blood-cell-count man, of high-blood-calcium man, and others over the surface of the earth. Study of such physiological characteristics is a part of anthropology that has been grossly neglected in the past. Surely it is fundamental to medical geography. We do not yet know to what extent "local" physiology prepares the subject for tissue impairment or pathology. We do not know definitely to what extent a man with 8 million red cells per cubic millimeter is susceptible to communicable disease or to noncommunicable disease, and how he compares, other factors being equal, in resistance to pathological change with other human types. In singling out the number of red cells it is of course understood to be just an index, and that many other physiological changes are coincident. Also, we may ask to what extent the low blood cell count of the tropics is the result of the climate alone or of the diseases that the climatic conditions foster. A complete analytical study of these various phenomena is needed.

A number of nonreversible pathologic changes seems to be closely related to the geographical environment. Let us consider cancer as an example. It seems to be well established that the rate of sarcomas and of melanoblastomas increases in both white and black races from temperate to tropical regions. The reason why primary cancer of the liver is so common in southeast Asia and in tropical

Africa is not clear; perhaps some clue can be found in an environmental study. In North Africa there seems to be a lower rate of breast cancer in the female, whereas the male seems to be more often affected than the European male: why?

Correlations between disease and geography. Some correlations between pathology and geography have been demonstrated. Thus noncommunicable diseases such as goiter, beriberi, and pellagra are explainable in terms of geographical correlations. We want to discover whether other such correlations would not shed considerable light on our knowledge of pathology.

Factors governing the distribution of communicable diseases can be classified in two groups, pathogens and geogens. Pathogens characterize the disease rather than the region; geogens characterize the region rather than the disease.

Included under the term pathogen are the agent —germ, fungus, or parasite; the vector, which carries the agent to the victim; the reservoir from which the vector picks up the agent; and the host, definitive or intermediate. All these combine in various numbers and proportions to constitute the pathological complex, the symptoms of which we call disease.[1]

Geogens may be classified as physical: altitude, temperature, soil, and the like; human: density of population, diet, income, etc.; and biological: the biota, blood groups, etc.

Medical geography brings together the pathogens and the geogens, with the purpose of delimiting zones where disease occurs and—perhaps even more important—delimiting zones where disease *might* occur if one of the elements of the complex temporarily missing is suddenly introduced. During the war in southeast Asia Allied troops were decimated by scrub typhus. The land where these troops were introduced was a pathological trap. Disease was potential there because there were present: (1) rat reservoirs, which carried the agent rickettsia in their blood; (2) the larval mite, vectors of the disease from rat to man; and (3) the environmental grass on which the adult mite feeds. The only missing element was man.

It is believed that the stage is set at the present time for an outbreak of yellow fever in India, where the vector is present, where man is present, but where, apparently, the virus has not yet been imported. Many other examples could be given that would show the possibility of forecasting outbreaks of epidemics as soon as the required environmental factors are gathered together. Such information is essential, among other things, to sound military planning, but analysis of the complex is not a simple matter; the interacting effect of certain geogens, such as temperature and humidity, may make correlation difficult. But however difficult the interpretation, analytical studies should be carried out both in nature, when possible, and in the artificial environment of the laboratory, each pathological complex being broken down into its component elements. Synthetic studies of groups of factors on a regional basis should be pursued simultaneously.

Noncommunicable pathology also has its environmental correlations. It is well known that heat brings about peripheral vasodilation, drop in blood pressure, acceleration of the heart, anoxia of the deep organs, water shifts, respiratory changes, concentration of urine, etc. If these changes are spontaneously compensated they do not come within this purview, but it is possible that at the time of their occurrence they put the subject in an unfavorable condition in regard to other attacking pathogens. In such case the measurement of the reversible phenomena becomes an important function of medical geography.[2]

If noncommunicable pathological conditions permanently affect the individual, they should be studied regionally by breaking down as far as possible the geographical elements and the physiological mechanisms sensitive to the environment. It would be profitable to examine in a significant number of cases the diverse liver functions in different climatic regions of the globe or against isolated climatic factors in the laboratory. Also, kidney and glandular variations in function could profitably be studied throughout the world if it were possible to finance such an enterprise. It has been done so far in isolated instances, but a strictly comparative study has never been undertaken.

Nonreversible pathology has been correlated with the environment in so many instances that our faith in pursuing such investigations appears to be justified. The correlation of skin neoplasms and radiations of allergic disorders with pollens or animal allergens of nutritional disease and soil; of degenerative diseases of the bones and joints with mineral contents of water and food—for instance, trace elements and fluorine content[3] of water in relation to dental disfiguration—are now well established and show what further systematic studies along these lines might teach us.

Medical geography is not a new science; rather, it offers a new approach to old problems, in some instances by providing a useful working hypothesis. As a first step in medical geography it is suggested

that a thorough census of our knowledge be made. A program is under way at the American Geographical Society to achieve these aims, by the compilation of an "Atlas of Disease," which would put on maps and diagrams all we know about the distribution of disease. A second step is to devise a better system of notification of disease than now obtains, for the purpose of getting at the real facts of distribution. It could be achieved by submitting selected samples of populations in a circumscribed environment to multiphase check-up for detection of the various diseases that have left traces in their organisms.

Further steps in the advancement of this branch of science may be expected from the work of the Commission for the Study of the Problems of Medical Geography, created at the International Geographical Congress in Lisbon in 1949.[4]

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[*Continued on advertising page x*]

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BOOK REVIEWS

MICROCLIMATES

The Climate near the Ground. Rudolf Geiger. Trans. by Milroy N. Stewart *et al.* 482 + xxi pp. Illus. $5.00. Harvard Univ. Press, Cambridge, Mass. 1950.

GEIGER brought out his first edition of the work at Munich in 1927. It was translated into English and found very useful. His second edition appeared in Germany in 1941, but no copy was available for translation until after the close of war in 1945. Then, while factual checking and translation were in progress, Dr. Geiger was "found," with a third edition in manuscript form, only awaiting paper for its publication. He turned over to the translators the new materials which have made this second English edition of *Climate near the Ground* the virtual equivalent of his still-unpublished third edition.

The book is a lucid, orderly, and factual presentation of the multitudinous interchanges taking place between ground surface and air—Geiger calls it microclimatology. His handling of the meteorological data for these surface air layers is masterly and convincing. Like the true meteorologist, he wastes little space on conclusions and deductions at the end of each chapter, leaving the facts to speak for themselves. It is unfortunate that he did not have better access to non-German publications of the decade just past, and that the translators failed to insert footnotes bringing the volume up to date. Only 75 of the book's 987 references are to works published since the second German edition appeared in 1941.

Part One deals with the microclimate the characteristics of which are largely determined by proximity to the ground surface. Radiational heat transfer (incoming and outgoing types), conduction, eddy diffusion, air and ground temperature changes, humidity, and wind behavior—these factors are analyzed in their relationships to the microclimate of the air layer near the ground. Water and snow surface effects are similarly treated, as well as those of many different kinds of soil coverings.

Part Two carries the analysis on to cover the microclimatic effects of topography, crops, and forest stands. Plants and many forms of animal life are shown to be vitally affected by their microclimatic habitat, as well as by the macroclimate prevailing farther above.

The chapters dealing with man constitute the volume's weakest part, for there the author is obviously out of his own field. Although his early chapters present a clear picture of the "temperature inversion" phenomenon, and although he considers the "haze-hood" atmospheres over cities as an extension of his microclimatology, he fails to deal effectively with many phases of the urban air pollution problem which depend directly upon the microclimatic principles earlier set forth. He barely touches upon the many ways man so seriously disturbs his immediate climatic habitat (indoor and outdoors, for better or for worse). Here lies a field to be covered by someone more familiar with the interplay of both microclimatology and macroclimatology upon human biology in general.

Climate near the Ground is indeed a valuable reference work for those interested in meteorology itself, in agronomy, horticulture, forestry, animal husbandry, and the varied phases of man's own contact with microclimatic problems over the earth. The volume is well done physically and is well indexed both for author references and subjects.

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LIFE IN THE OCEANS

The Sea and its Mysteries. John S. Colman. xvi + 261 pp. Illus. $3.75. Norton, New York. 1950.

ONCE again, another excellent British book on natural history is offered to the American public. Colman's book is a well-written and authoritative account of the present status of oceanography. With its popular treatment of modern fisheries, circulation of deep water, currents and waves, and the migration of marine animals, it should prove very useful as supplementary reading for students of marine life.

The first third of the book outlines the major problems of physical oceanography. The last eight chapters deal entertainingly with life in the depths, life between tidemarks, coral reefs, and the migrations of whales and fish. A particularly interesting summary is given of the recent developments in fisheries investigations—particularly of the advancements in methods of predicting the migrations and abundance of important food fishes in northeastern Europe. Two pages of conversion tables (meters to fathoms and Centigrade to Fahrenheit) and a short list of reading matter on the sea are appended at the end of the book.

John S. Colman is at present the director of the Marine Biological Station at Erin, Isle of Man, and his wide practical experience with marine zoology and the ocean have given him ample background for this introduction to oceanography. This book is in marked contrast to the number of extraordinarily poor natural history books that are being written by pseudo-scientists and being published with reckless abandon by some American houses.

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ON THE DEPLETION OF OUR RESOURCES

Water, Land, and People. Bernard Frank and Anthony Netboy. 331 pp. Illus. $4.00. Knopf, New York. 1950.

AN OBSERVANT traveler in the United States cannot be otherwise than shocked at the extent to which agriculture, industry, and urbanization in general have caused the ruination of many streams and rivers. Indeed, the use of our waters as dumps for the disposal of trash, sewage, and industrial waste is a national disgrace. But this kind of stream pollution can be corrected in short order and at a cost that most states and municipalities can afford to pay, if they really want to do the job.

Not so easily corrected is the mutilation of our nation's watersheds, which have been steadily deteriorating as a result of destruction of forests by fire and wasteful cutting, overgrazing of grasslands, and erosion-inducing farm practices. The consequent reduction in water supply and the increased siltation of stream beds are problems that governments and people have got to face if we are to continue to enjoy our American way of life.

Dams, levees, and reservoirs, though often essential for the control of stream flow, are not the solution for wrecked watersheds. Without watershed management, river development by engineering structures is at best a stopgap, temporary, costly, and sometimes futile. Our most indefatigable dam-builders—the Corps of Engineers of the Army and the Bureau of Reclamation of the Department of the Interior—have both been harshly criticized by the Hoover Commission for their feuding, their competitive extravagance, and their waste. In the opinion of Frank and Netboy, the public interest "would best be served by holding in abeyance many of the dams now proposed until thoroughgoing plans for the restoration of the watersheds above them have been presented to the public."

Here we have described the cumulative effect of two centuries of land misuse. Realistic, eloquent, and informative, the book provides numerous interesting examples of local water problems which cannot help but fascinate the well-informed, public-minded reader. The scientist, and in particular the teacher, will find much to ponder in this authoritative work. Well and simply written, it contains a minimum of technical terminology.

The authors propose no glib and easy solution. They argue against pork-barrel projects such as the defective Pick-Sloan plan for the Missouri Valley; and they are lukewarm toward the much-debated river basin authorities, although with some reservations they endorse the Tennessee Valley Authority. A Federal agency with the planning and coordinating functions of the former Natural Resources Planning Board is their recommended procedure for handling water conservation and development.

First, however, they make a persuasive plea for increased research, especially to provide information on precipitation and stream flow for our thousands of small watersheds, for soil and topographic maps where these are not available, and for more exact data on the extent and capacity of ground-water resources. In short, since water is the lifeblood of this nation, we need to know more about the nature of watersheds and how to manage them.

A timely and significant book, carefully documented, beautifully illustrated, and attractively printed, *Land, Water, and People* is recommended reading.

HENRY CLEPPER

Society of American Foresters
Washington, D. C.

PANTHEISTIC FORESTRY

A Natural History of Trees of Eastern and Central North America. Donald Culross Peattie. 606 pp. $5.00. Houghton Mifflin, Boston. 1950.

PEATTIE has always found it fun to read a thick unabridged dictionary for an hour or two at a time. This semipopular book on North American trees east of the Rockies is interleaved with scraps of tree lore, now a bit of etymology, now a story from pioneer America, all casually intermingled as so much deep duff in old woods. Representative of the hundreds of etymologies is how "hackberry" may be traced back to hagberry. But some engaging lore about "loblolly" and the symbolism of *Pinus pinea,* to mention one instance, is missed. Though this is no book to rename the tags in the arboretums of America, and hardly equal to the jacketeer's line "nothing like it has ever been published," it is a distinguished book, and for two reasons: its woodcut illustrations and its highly readable commentary. Paul Landacre's woodcuts are pleasing and may help the novice in many instances (not in *Crataegus*), though they are plainly more art than botany. Too many leaves of trees in the pitch of anthesis show temporary wilting or curl with the foreboding of autumn.

Peattie's narrative will contain some kernels of information for even the veteran dendrologist. If, for instance, he opens at "Sweet Gum," he will read of Don Bernal Diaz del Castillo, Francisco Hernandez, Cabeza de Vaca, of "Satin Walnut" in Britain, of the tapping of *Liquidamber* in Alabama during the second world war, etc. Some of the stories are highlighted with at best only good historical guesses. Much of the detail for the travels and times of Michaux is still very incomplete, and any conclusion as to where such and such a tree was first discovered is yet to be documented from a broad synthesis of evidence. Nevertheless, the book is rewarding for casual browsing and will introduce many readers to rich woodlands of tree literature and garrets of history. Peattie is, after all, still a toolshed word for those soilless plantsmen who prefer to dig plant lore from books in an easy chair. Each tree is described, designated both by its scientific and folk names, and its range is stated in some detail from information checked by Norman C. Fassett, of the University of Wisconsin. Some unfamiliar tree names are brought out here as being more authentic than the

familiar. Thus "sarviss tree" replaces service berry; "rowantree," mountain ash; but dogwood is not replaced, as well it might be, by "dagwood!" *Cornus alternifolia* seems to have been called "pigeonberry" in only a restricted region of New York State, according to George B. Sudworth, and there only during the heyday of the passenger pigeon. The name is often applied to the verbenaceous shrub *Duranta repens* of our gardens, and the names "blue cornel" and "alternate-leaved dogwood" are certainly more familiar to common folks, even the "amateur mountaineers or other hyperthyroid fauna." The passenger pigeon, says Peattie, was exterminated "as much by the disappearance of beech mast as by mass slaughter," but I have found no support for this contention in the ornithological accounts at hand.* Granting that the beech mast required by the pigeon legions could only be computed in tons, it is still unlikely that the primary responsibility of man in the debacle can be shifted.

One eighth of the book's 606 pages are blank! These 74 unnumbered blank pages separate the genera throughout the text; there are many instances where woodcuts now scattered in the species accounts might have been moved to these blank pages to advantage (e.g., tulip tree on p. 269 to p. 266; sassafras, on p. 292 to p. 290, etc.).

This "survey of the great American sylva" is replete with that narrative style for which Peattie is famous. He writes of the sweet locust: "this is a slow tree to leaf; long after other citizens of the forest are clothed in foliage, the fiercely thorny, dark-barked Honeyshucks stands naked and secretive, as if refusing to yield to the persuasions of spring." No convert of a parthenogenetic matriolic religion, he is a stout pantheist from the days of the "odor of the Lindens in bloom" that "brings back the soaring wail of the tree toads, the first fireflies in the dusk, the banging of June beetles on the window screens, the limpness of the flags at Fourth of July, and all that is boy's-eye view of those languorous first days of vacation from school." Again: "The elms are backward, and the crocuses look bullied by the wind; the oaks are still asleep. It is the hour, though, when creatures have the same aching restlessness that we call spring fever." But this last quotation is Peattie fifteen years ago!† Too, this narrative has "an epic line in pure American vein," and one is forcibly persuaded that most of the trees of America are as endemic as Saratoga chips, the tallest, and altogether the finest in the world's forests! He writes in the spirit of Humphry Marshall of 1785 when he says: "[the native American linden] has rivals in a number of Lindens of European origin, including many hybrids. Some of these are preferred for their pretty little leaves, and their profusion of flowers. But none of them equals the American Linden . . .!" The book closes on a philosophic note: "Each [tree] has its place; each is, or it was in the days of virgin innocence, adjusted to its environment and held with its neighbors in a precise ecologic balance.‡ All are equal in the sight of an impartial Nature. All are fellow citizens of the grand American sylva."

JOSEPH EWAN

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* *Cf.* A. C. Bent's *Life Histories of North American Birds* (U. S. Nat. Mus. Bull. 162, 388 [1932]) and the references given therein.

† *Almanac for Moderns,* 386 (1935).

‡ Peattie conceives of forests, not in dynamic succession as did his Santa Barbara neighbor, the late Frederick Edward Clements, but in a kind of stable equilibrium. Change, on the contrary, must be granted as the first and last rule in the ecology of the forest.

AN ENCYCLOPEDIC WORK

The Evolution of Scientific Thought. (2nd ed.) A. d'Abro. xx + 481 pp. Illus. $3.95. Dover Publ., New York. 1950.

THIS book is a second edition; the first edition was published in 1927. The author states in his preface that certain slips and errors in the first edition have been corrected and that the chapter on the finiteness of the universe has been entirely rewritten.

The author reviews the essential features of Newton's discoveries; he then takes up the work of Riemann and others, who developed non-Euclidean geometry a century and a half after Newton. Fifty years later, Einstein combined the work of Newton and Riemann, giving us thereby that supreme achievement of modern thought—the theory of relativity.

This book is not to be regarded as a textbook of relativity; it covers too much ground in a small space for that. It requires in the reader a mental background in mathematics that exceeds that of the average college undergraduate. It is rather to be regarded as an encyclopedic work that will take an important place in the study library of scientists, philosophers, teachers, and graduate students.

The eighteenth century was no mean or unfruitful period in physical science. The scientific workers of that day were diligent explorers in an unworked field, but their mental attitude was materialistic to a degree which it is now difficult to realize. These workers studied matter only; the concept of energy was not yet recognized. Forces were indeed known, gravitational, mechanical, electrical, and magnetic, but all were regarded as properties of matter, secondary and subordinate in their nature.

The nineteenth century was a century of correlation. This began with the work of Davy and Rumford on the correlation of heat and work. Another correlation was that between electricity and magnetism, resulting from the work of Oersted and Faraday. Later came the work of Maxwell on the electromagnetic theory of light.

But up to the close of the nineteenth century gravitation had resisted all attempts to correlate it. It remained alone, untouchable and universal in its domain. It was reserved for Einstein, early in the present century, to correlate gravitation with inertia and optics. D'Abro's book tells the story of how this was done.

Many interesting quotations from the book might be given; two may suffice.

> Had our solar system contained two suns, such as are present in double star systems . . . it is safe to say that Newton, in spite of his genius, would never have discovered his law of gravitation; for he would have been thrown back on the tremendous problem of three bodies.

Again, after several pages devoted to the criticisms of scientific thought made by philosophers, the author says:

> It is important not to confuse the meaning of the words "absolute" and "relative," as used by physicists, with their meaning as understood by philosophers. Much of the difficulty that philosophers appear to have experienced in understanding the attitude of scientists seems to have arisen from confusions of this sort.

This book is well worth careful study by those who have the necessary background.

PAUL R. HEYL

Washington, D. C.

KENNETIC INQUIRY*

Knowing and the Known. John Dewey and Arthur F. Bentley. 334 pp. $4.00. Beacon Press, Boston. 1949.

THE verb "know" in virtually all its uses indicates something a man "does;" the noun "knowledge," similarly, something a man "has" (see the sixteen columns in the *Oxford Dictionary* on words of this cluster). This treatment, derivative of medieval soul or spirit, assumes mental actor as opposed to physical material. What happens to it if knowings and knowns submit themselves to research under methods akin to those of modern science?

John Dewey and Arthur F. Bentley have joined in seeking an answer. Dewey brings to this task his unparalleled range of philosophical appraisal, Bentley his long concentration on straight wordings and adequate postulations for behavioral inquiry. The two find themselves in substantial agreement at every step in problem-formation, strategy of attack, and indicated outcomes. They reject all the old verbal fixations, both explicit and implicit, including entitative "sensations," "percepts," "ideas," "concepts," etc., so common to the usual treatment of "knowledge" problems. This they do to free the way for straightforward observation and description, under postulation, of organisms dealing with world in the process of knowing. Here neither organisms nor world is taken as "isolates" or "absolutes" in any way. The postulations they adopt are fully tentative as befitting the present early stage of their work.

For the old equipment of terms and corresponding entities, they substitute naming under postulation; and this in much the same sense that the electron as something named gains its status in physics. Such postulation demands verbal precision, and the authors send up a series of trial balloons in search of firm names for their work and for purposes of communication among other workers. But along with this precision these inquirers pledge themselves in the fullest sense to the standards of observability, understanding thereby, not reports of vision alone, but whatever can be achieved by the organism in action, intent upon its problem, and using all the probes at its command.

In this setting the human organism is accepted naturalistically in the cosmic system. Knowings and knowns enter as phases of specific events and so only. They enter under the postulate that without the knowings we have no knowns (once verbal trickery and magic are rejected) and that without the knowns no knowings; and that the cosmic "transactions" of the "knowings-knowns" are such that all "outside" pretenders to the status of the knower or of the reality-known are eliminated. In similar postulation, words and their meanings become aspects of one process—no meaningless word admitted and no disembodied meaning for a word. Such postulates—there are a dozen or so more—require extended protective statement, impracticable in a review. I mention only one more: that full durational setting, not merely "clock-tick" time, is essential for description. Similarly, full spatial setting of events is insisted upon by these researchers. In so doing, they take for themselves the freedom to work within spatio-temporal frameworks that are best suited for the making of progress with the problematic materials they face. Other scientists might well take notice of, and, perhaps, emulate, this procedure.

The development of the book sets forth a technical differentiation between behavioral and physiological inquiry, akin in type to that between physiological and physical. It identifies the behavioral as sign-process, and treats sign-process as knowing-process in the broadest sense of "know." The name "Signal" is adopted from Pavlov for the lowest evolutionary stages of behaviors, covering all directly sensorial-perceptive-manipulative activity. Above these, Designations (or Namings) are exhibited as arising from Signal, and working toward its increased efficiency. Naming appears in three stages: Cue, Characterization, and Specification (the top specifications being those of science). Finally Symbol, mathematical and logical, is differentiated as coming to the aid of Designation, much as this latter came to the aid of Signal.

The book is tightly written, making little compromise with conventional expression. Perhaps half its space is given to displays of radical incoherence in the old procedures centering on man-the-actor—the more pretentious these procedures are, the worse they are made to appear. The book does not pretend that the work therein reported attains full scientific status. Rather, it is a start in that direction. Before Einstein, space and time were "formals" or "absolutes" not themselves inside the range of scientific research. Today the Mind-Knower and the Real-Known are similar "formals," thumbing their noses at research and seeking to claim formal and final acceptance from most scientists. The Dewey-Bentley project seeks the capture

* See the article by this title in SCIENCE, 112, 775 (1950).

of these descendants from the far nonscientific past and their domestication within scientific research.

SOLOMON WEINSTOCK

Indiana University

WHAT PLANT IS THAT?

Gray's Manual of Botany. (8th ed.) Merritt Lyndon Fernald. lxiv + 1,632 pp. Illus. $9.50. American Book Company, New York. 1950.

FOR twenty years it has been apparent to students of American botany that a revision of the seventh edition of Gray's *Manual* was needed. Last year it was finished and went out to reviewers scarcely a month before news came that Professor Fernald had passed on. It is a fitting and probably long-lasting monument to a great taxonomist, a book whose further revision will not be undertaken lightly.

Forty-two years have passed since Fernald and Benjamin Robinson revised Gray's "handbook," a guide to the flowering plants and ferns of the central and northeastern United States and adjacent Canada, to cover some 4,885 species, varieties, and named forms in a book of 926 pages. The present volume includes approximately 8,000 species and varieties, as well as a masterful introductory synopsis of the orders and families of vascular plants, showing the fundamental principles upon which the classification of earth's higher plants is based. It runs to 1,632 pages.

The sequence of families adopted is the familiar one of Engler and Prantl. Other systems based on geological evidence that suggests more probable avenues of evolution, floral elaboration, or changes in seed structure have been suggested, but the man who had to do the work chose to ignore elaborate hypotheses and adhere to the system most familiar to all but British botanists.

In the midst of all the changes in geographic distribution and hybridization caused by mankind's interference with nature, what constitutes a good species plagued Fernald even more than it has other working taxonomists. "By their fruits ye shall know them" is the starting point for most critical classifications, and that includes when possible, he says, "flower, fruit, seed or spore." Plant species as he further conceived them are "a series of individuals (usually numberless) occupying, until disturbed by man's activity, a natural geographic area and having essentially identical morphological characters of flower, fruit or reproductive structure."

A great help to both the professional and amateur botanist is the new division of the index section into one part for Latin names of families, genera, and species and another part for English, French-Canadian, and colloquial names.

Valuable additions were made to the glossary in this new edition. Without careful explanations of terms used in the complicated business of plant identification, this eighth edition would occasion a great deal of exasperation. Many commonly used botanical descriptives either cannot be found in Webster's or have a meaning that botanists consider all their own. When it comes to splitting hairs, for example, a botanist is more adept than a dozen microscopists. A few minutes in Fernald's glossary will disclose more ways of expressing the hirsute gradations from thistledown fuzz to bristles than there are letters in the alphabet to use for subheads.

How simple it would have been for Fernald if he had lived in the days of Amos Eaton, who published the fifth edition of a botany manual in 1829 and wrote: "Many vain botanists are continually in search of new species; and their vanity leads them into gross absurdities. . . . There *is* not probably 50 undescribed species of *Phenogamous* plants in the United States, perhaps not one species east of the Mississippi."

Plant species in Eaton's day were arranged with the genera in strictly alphabetical order, with no designation of families and orders. His was the "voice of authority," and established usage carried more weight than historic specimens. Taxonomy was finished!

But with today's emphasis on historic types and strict priority of publication, taxonomists must be bookworms and herbarium botanists as well as fieldworkers. Fernald's work had to be slow and exacting because it was necessary for him to examine the groundwork of all suspected poor species. Even his beloved pondweeds (*Potamogeton*) lost their place as Najadaceae and became a tribe of the Zosteraceae.

In the years to come it will be interesting to see what happens to some of the notoriously unstable groups that in this edition have experienced widespread changes: the Orchidaceae, whose new treatment is scarcely comparable to that accomplished by Oakes Ames in the previous edition; the Gramineae, considerably overhauled since A. S. Hitchcock made his final revision; *Rubus*, enriched from a scant 38 allowable species to a new boisterous 205; and *Crataegus*, which now boasts 103 species under E. J. Palmer treatment, instead of the 65 allowed by W. W. Eggleston. Yet these may be only first bubbles in the boiling taxonomic cauldron as cytology, genetics, paleobotany, plant physiology, and biochemistry stir the fire.

Establishment of the International Rules of Botanical Nomenclature and the wealth of accumulated new knowledge gathered by active field botanists (within the manual range especially) made the present revision seem an endless task. All the while it was in preparation there were routine tasks and honorary impedimenta to surmount until it must have seemed to Fernald it would be preferable to count orchid seeds or say the *Pater Noster* backward than answer again the query, "When will the *Manual* be ready?"

But what seemed to him the last straw came floating by in 1939, long after the pondweeds were done:* "The meddlesome young botanists at the British Museum have just brought forward the assertion that the one and only specimen before Linnaeus in originally describing *Potamogeton pusillus* has never before been critically examined by a student of the group, although the famous English student of the genus . . . had always

* "How Soon Will the Manual Be Done?" SCIENCE, 89, 329 (1939).

lived within an hour's ride of it. It is not at all what every one calls *P. pusillus* but another species. Now we must start all over again!"

Fernald had help with his new edition, for it would be far too much to expect any one man to tackle alone. His list of "those to whom special appreciation is due" constitutes a Who's Who of mid-twentieth-century taxonomists, especially in manual range.

However, there will be many among the "little people" of botany who will wish he had found more room for mentioning first discoveries. Furthermore, some of the more classically minded students will dislike certain new Latin spellings. In these, however, he had the expert advice of A. S. Pease, of Harvard, a Latin scholar as well as an accomplished botanist. Others will wish that Fernald hadn't extended the manual range once more to include species that definitely belong to the Southern coastal plain. They seem like strangers in this book, more so perhaps than other newcomers added because of Fernald's intense interest in the Gaspé Peninsula and adjacent parts of southern Canada and Newfoundland.

Perhaps his greatest achievement is the perspective he has drawn for future students, pointing out that although botanical knowledge of the region he knew so well vastly multiplied in the years he devoted to his field and "closet" work, the "manual range" is still full of absorbing and unsolved problems.

In the years to come only those who become part owners of this book can truly appreciate how great a monument it is.

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BRIEFLY REVIEWED

Practical Photography. Robert A. McCoy. xv + 221 pp. Illus. $4.00. McKnight & McKnight, Bloomington, Ill. 1950.

MR. MCCOY seems a little coy when he states that his book *Practical Photography* is written as a nontechnical text for high schools, a beginning course for colleges, and a guide for amateurs. What he forgot to say was that he neglected to tell how to make photographs; instead, he clutters the first third of the book with such nonsense as diagrams showing the formation of an image through a pinhole and, to make things more confusing, a comparison scale between U. S. and F stops. There is no lens made in the world today, nor has one been made for several decades, with the U. S. stops. The chapter on lenses is concluded with the brilliant observation that a lens should be kept in the best of condition if it is to perform properly.

By all standards, enlarging is the most critical step in photography, wherein deft skill is the difference between a good or a bad picture. Exactly twelve pages of extremely inept remarks are devoted to this phase. Example: "To enlarge twice the size of the negative the distance from lens to paper should be $(2+1) \times$ focal length of lens, etc."

If McCoy imparts no more practical information to his students at the University of California than he does in his book, I can readily understand why I meet so many would-be photographers who profess to have studied under this or that professor, but always when asked for samples of their work reply that they left it at school.

A. AUBREY BODINE

Baltimore Sunday Sun
Baltimore, Maryland

The Greek Philosophers. W. K. C. Guthrie. v + 168 pp. $2.75. Philosophical Library, New York. 1950.

THE basic preconcept in this pocket-size book is that, although a knowledge of the Greek language is not essential for its reading, no one can understand completely the arguments of the Greek philosophers without a study of the language. What the fifth-century B.C. man meant by "justice," "virtue," and "god" is entirely other than our own use of the words. Thus it is necessary to get inside the Greek mind, to look at Greek ways of thinking, if the philosophy is to be studied.

The book is the work of a Cambridge University professor and is based on his lectures to his students. It is the kind of book every student will welcome. Complete with index and suggested further reading, it gives in compact form everything that all but a philosophy major may wish to know.

The Ionian or Milesian school (Thales, Anaximander, and Anaximenes), with its "What is the world made of" question, opens the book. The philosophy of Pythagorus, Heraclitus, Parmenides, and Democritus, known as the Italian school, is clarified. Midway of the fifth century B.C. the humanists took over Greek thought; with no means of experimentation or applied science, their emphasis was on man. First were the Sophists, then came Socrates, Plato, and Aristotle.

Each school was influenced by the preceding one; each philosophy was directly opposed to some part, at least, of an earlier one. The author makes no comparisons and seeks no parallels with modern philosophies. For the reader however, they are inescapable. At any rate, the foundation of modern ideas—up to the twentieth century—is found in Greek philosophy. The old way of thought is available here to every searcher of the new.

MARJORIE B. SNYDER

Washington, D. C.

LETTERS

MORE ON PLANNED ECONOMY*

Mr. Thomas' letter on my article "Planned Economy: Good or Bad?" (SMO, November 1950) interested me very much. He has his version of the material I quote, and I have mine. The reader is always at liberty to examine the full text for himself. But, after pushing away the underbrush of quotations, of the various viewpoints on Great Britain's socialist experiment, of the degree of planning in our own economy, etc., we come to the core of our disagreement, which is truly the prime issue of the day. It is epitomized in Thomas' statement: "We democratic socialists believe that the great American community, loyal to the principle of cooperation for achieving plenty and peace and freedom, *will make extensive use of government as our servant*" (italics mine).

If one believes that the government can be given complete monopolistic power over the economy and still be the people's servant—a humble servant and yet be omniscient enough to run the economy for the welfare of all the people—he would follow Thomas' thinking. If one questions this premise—and who is there who has played an active role in government or in a decision-making position in industry who does not question it?—the whole socialist and planned economy position becomes untenable.

One would like to think of an orderly world where men acted in a rational way in the best interests of all the people. But both history and an analysis of oneself indicate that man does not always act intelligently and orderly—more often than not he acts emotionally, very irrationally, and in a highly individualistic manner. It was this bit of wisdom that caused our forefathers to analyze the history of economic systems, which with few exceptions have been centrally controlled, and forced them to realize that man could be truly free only when government was kept at a minimum by checks and balances so that the people could exert control over government servants.

Human experience in history is full of the corrupting and tyrannical influence of men in control of the state. Just how the people are going to exert their mastership over the government as their servant when the "servants" have complete economic control over the people is the very heart of the problem which besets us. Government "servants" with less power than they would have under socialism or any form of a planned economy have never shown that they acted any more wisely and with less emotion than the people in general, and in innumerable instances they have not acted at all like "servants" but very much as masters. What can be expected when they have more power?

It is around this point of the government's role which the doubtful person on the subject of "Planned Economy: Good or Bad?" might direct further studies. There are innumerable ramifications going into decision-making, motivation, desire for power, the political franchise in economic affairs versus the economic franchise of voting by buying or refraining from buying a given product, *et al.*, which throw more doubt on the ability of planned systems to provide the "plenty" needed for welfare. The literature is full of historical data, but none proves that concentration of political and economic power can be anything but dictatorial and a long way from being the people's servant. Fortunately, with planned economies a reality in some parts of the world and not just utopia, their actual practices give us ample room for scientific study as to their limitations and inadequacies in comparison with a free market economy.

Ruth Shallcross

The Institute of Paper Chemistry
Appleton, Wisconsin

Dear Dr. Shallcross:

A FRIEND of mine has kindly called to my attention your article in The Scientific Monthly for November. I read it with very great interest and with complete approval; I wish to thank you for taking the time to write such a sound and lucid document. I hope it may be circulated widely. Of course every economist who is a "planner" should have a copy, as should every member of Congress. I hope a copy goes to the *Reader's Digest*. (I am calling the article to the attention of DeWitt Wallace.) Are reprints available? Do you have an extra copy I could send to a Congressman for insertion in the *Congressional Record?*

All power to your pen; your contributions are surely needed these days.

Walter E. Spahr

Economists' National Committee
on Monetary Policy
New York

* Correspondence on this subject closed.